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## THE PELTON WATER WHEEL.

(Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Lester A. Pelton.)

HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, November 2, 1894.

The Franklin Institute of the State of Pennsylvania, for the promotion of the mechanic arts, acting through its Committee on Science and the Arts, investigating the Pelton water wheel, reports, that:

The Pelton water wheel is what may be termed an impulse reaction wheel, the power of which is derived from the pressure afforded by a head of water, supplied by a line of pipe, discharged upon it through a small nozzle, the size of said nozzle being proportioned to the amount and head of water available, and to the power required. The manner of utilizing this pressure is the distinguishing feature of the invention and the secret of its success.

The plane of the wheel is vertical, turning upon a horizontal axis, the bearings of which are mounted and fixed upon a wooden or metal frame, to which also the nozzle is attached, making the machine, as a whole, self-contained. The bearings are accessible at all times for examination and lubrication, and are easily protected from water and grit.

Over the wheel, but not touching it anywhere, is placed a cover for withholding the sling of the water from the wheel, and directing it vertically downward to the tail-race, whence all waste is carried away.

It has a number of buckets or cups, like *Fig. 1*, fastened to its periphery, each provided with a wedge dividing the jet (which is applied tangentially) into two parts, one turn-

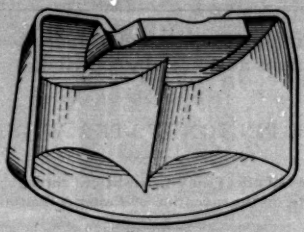

FIG. 1.

ing to the right, the other to the left (shown in section in *Fig. 2*), the direction of both being almost completely reversed before the water leaves the bucket. To facilitate the escape of the spent water and to utilize all of the head, the stream is usually applied to the lower side of the wheel. The object in this, as in other wheels, is to receive the water without shock, to discharge it without velocity, and to apply the energy thus liberated to turning the wheel in the most efficient manner.

The Pelton wheel was developed in the mountainous regions of California, and was tested and improved by men who knew its value. It was eminently suited to the conditions existing in such localities, where water was to be had under high pressures and where portability of the wheel was

essential. In the early days of mining, when roads, or rather trails, were few and rough, much of the machinery had to be transported on the backs of mules and burros, which animals were capable of carrying a load of about three hundred pounds. Lightness, was, therefore, a most important feature; and that this was realized to an important degree in the Pelton construction may be seen by the following examples of wheels working under high pressures.

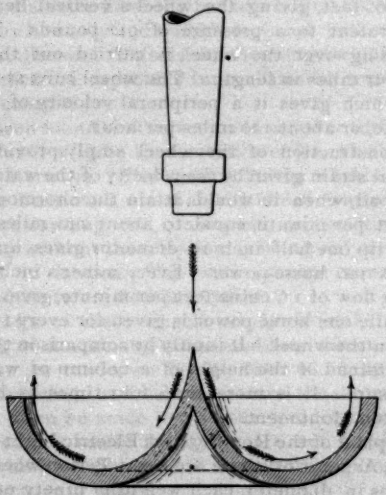

FIG. 2.

In the Comstock mines at Virginia City, Nevada, are located six wheels, each weighing 220 pounds, developing 125 horse-power each with a stream five-eighth inch diameter, and a head of 1,680 feet. They are forty inches in diameter, are made of phosphor-bronze, and run at a speed of 900 revolutions per minute.

Probably the most extraordinary water-power installation, so far as head is concerned, that can be referred to, is

that made some two years ago in one of the famous Comstock mines, at Virginia City, Nevada.

This consisted of a thirty-six inch Pelton wheel (*Fig. 3*), made of a solid steel disk, with phosphor-bronze buckets securely riveted to the rim. It is located at the Sutro Tunnel level of the California and Consolidated Virginia shaft, 1,640 feet below the surface. In addition to the head afforded by the depth of the shaft, the pipe is connected to the line of the Gold Hill Water Company, which carries a head of 460 feet, giving the wheel a vertical head of 2,100 feet, equivalent to a pressure of 911 pounds. The water, after passing over the wheel, is carried out through the tunnel, four miles in length. The wheel runs at 1,150 revolutions, which gives it a peripheral velocity of 10,804 feet per minute, or about 120 miles per hour.

The construction of the wheel amply provides for the centrifugal strain given by the velocity of the water, running without load, when it would attain the enormous speed of 21,608 feet per minute, equal to about 240 miles per hour. A nozzle tip one-half inch in diameter gives under above conditions 100 horse-power. Every miner's inch of water, equal to a flow of 1·6 cubic feet per minute, gives five horse-power, while one horse-power is given for every two pounds of metal in the wheel. It is only by comparison that an idea can be obtained of the height of a column of water due to such pressure. It is more than four times as high as the Washington Monument.

At the plant of the Roaring Fork Electric Light and Power Company, Aspen, Col., there are eight Pelton wheels twenty-four inches in diameter, each weighing ninety pounds, and capable of developing 175 horse-power, or about two horse-power for each pound of metal in the wheel. The speed is 1,000 revolutions per minute, and the head 820 feet. The complete outfit, including shaft, boxes, pulleys, gate and nozzle, weighs four and one-half pounds per horse-power developed.

The extreme simplicity of these wheels renders them strong and durable, not liable to get out of order, and enables them to be run with a minimum of wear. Breakage

seldom occurs; the wear is confined to the large shaft bearings and to the vane surfaces over which the water passes. There are no running water joints to preserve, and the nozzle is of the simplest and most efficient form, the cylindrical jet being commonly used. The path of the water in the bucket is short, reducing friction to a minimum. If the water carries abrasive materials, the effect is sometimes seen on the wetted surfaces, but the wear is slight, and never detrimental to efficiency. Then again, all the wheels above two feet in diameter have the buckets bolted on, so that one or more may be easily and quickly replaced without disturbing the installation. This is an advantage which is everywhere appreciated, especially in localities far removed from industrial centres.

It has been found that in very cold weather turbines have been interfered with by the formation of ice, which clogs the joints of waterways. The 24-inch Pelton wheels at Aspen, Col., before mentioned, are at an altitude of nearly 8,000 feet; but notwithstanding the consequent severe winters, they are running without interruption, it being only necessary to keep them in motion. The water cannot remain in the wheels, and therefore does not freeze.

The shafts of these wheels are horizontal, facilitating the driving of machinery, often enabling direct shaft connections to be made, as in the case of many electrical plants. Knowing the head or pressure, the diameter of the wheel can often be made to give the speed required. Such applications are easily made, but are not possible in all cases, as where a high speed is wanted from a low head and a large quantity of water.

The tendency of modern machine practice is to introduce direct connections between the motor and the machine to be driven, thus simplifying the parts, reducing first cost and maintenance, and economizing space. The construction of the Pelton wheel enables this to be done in all cases where the head, which controls the speed of the buckets, is so related to the rotative speed as to give a wheel of reasonable dimensions (see *Fig. 4*). The minimum diameter depends, to a certain extent, upon the quantity of water to

be used; if this is large, it may be necessary to use more than one jet on the wheel, or to use two or more wheels on the same shaft, to obtain the required speed. The application of several jets to a wheel does not impair the efficiency when it is carried out according to well-known rules (see *Fig. 5*).

A consideration of the relative cost of installing a free jet wheel and another kind of wheel of equal power will convince any one of the advantage in favor of the former. The cases and foundations are light and simple, there are no expensive penstocks or draft-tubes, no inconvenient means of transmission, no heavy stonework.

Those who have been on the Isle of Man will remember the large overshot wheel at Laxey, with its massive work in the shape of foundations, towers, etc. (see *Fig. 6*). The wheel is seventy-two feet six inches in diameter, and develops about 150 horse-power, the power being used for pumping purposes in a lead mine.

A Pelton wheel, six feet in diameter, with this head, will develop the same power with much less water and with a great saving in first cost of wheel and installation, the proportion being probably fifty to one in favor of the Pelton wheel.

Hamilton Smith, Jr., stated before the American Institute of Mining Engineers, in 1884, that, to his knowledge, about 800 turbines had been taken out in California on account of wear and consequent low efficiency. Turbines have a distinctive advantage under very low heads, because of the large quantity of water which they can utilize, but under high pressures the speed becomes excessive and destructive. A free jet or tangential wheel may run to the limit fixed by the strength of the material without injury, there being no wear except in the bearings. The point at which it becomes advisable to use turbines depends, to some extent, on conditions other than pressure, and would have to be determined from the full particulars of the case.

The construction of these wheels indicates that a high efficiency may be obtained when running with a full or re-

duced water supply, and such has been found to be the case. Buckets are designed for a maximum diameter of stream, without reference to the head, but the only objection to using a much smaller stream would be the disproportion of weights and friction surfaces, an objection which is of very little practical importance. This method is adopted when the quantity of water varies, the minimum stream being often only twenty-five per cent. of the maximum. This can be done with no appreciable loss of efficiency, in strong contrast with the turbine, with its variation of twenty per cent., more or less, under varying gates.

In many cases of use in the mountains there is no need for governing devices; on stamp mills, for instance, when such are necessary, the method used will depend upon the water supply. If a liberal use of water is allowable, a nozzle is used having a ball-and-socket joint, which permits the stream to be partly or entirely deflected below the buckets (see *Fig. 7*). It is called a "deflecting" nozzle, and in its general features resembles the apparatus used in hydraulic mining.

The centrifugal friction governor has been used to a very great extent, the balls acting on a double-geared bevel friction wheel, which opens or closes a butterfly valve (see *Fig. 8*).

When a constant speed can be obtained from a source outside of the wheel itself, as from an independent motor, the differential governor is available (see *Fig. 9*). This consists of four mitre gear wheels in mesh, each forming the side of a square; two opposite gears being loose on the shaft and driven in opposite directions by pulleys and belts; the remaining two running free on studs, which project from a hub fastened to the same shaft. So long as the pulleys run at the same speed there will be a simple rotation of the gears on their axes; but if one runs faster than the other, the gears on the studs will be revolved bodily around the shaft. This motion, which is very sensitive, is made to open or close a butterfly valve in the service pipe. Safety stops are provided at full open and full shut, to prevent the governor from binding the valve and

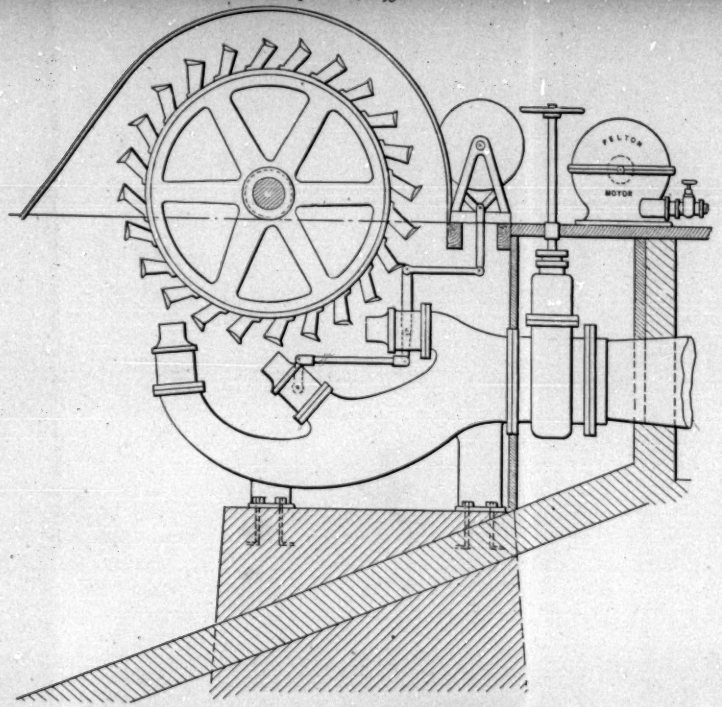


FIG. 5.

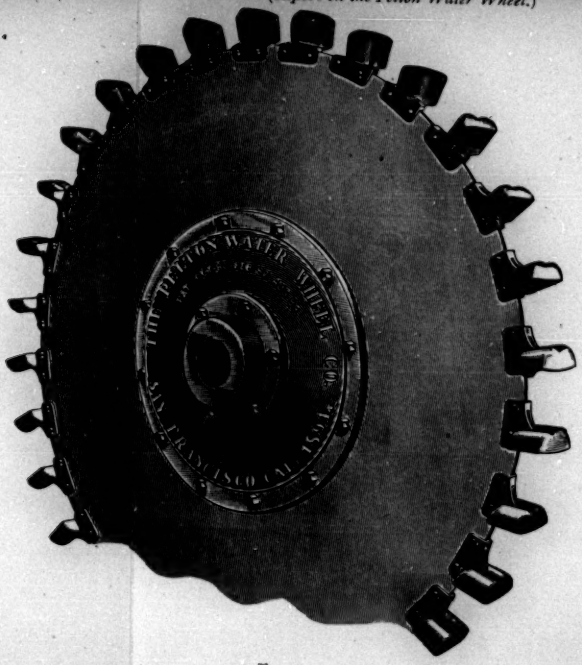


FIG. 3.

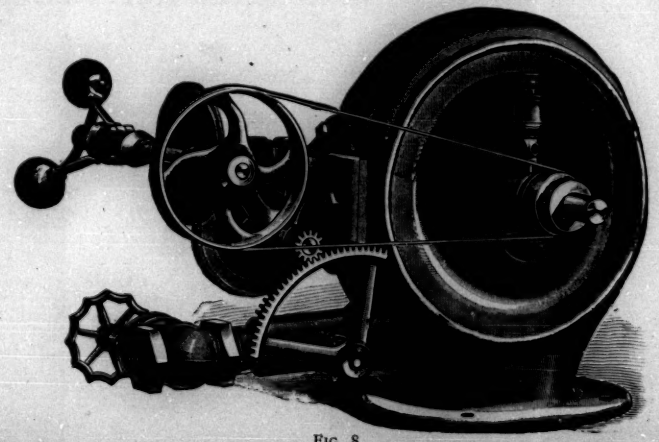

FIG. 8.

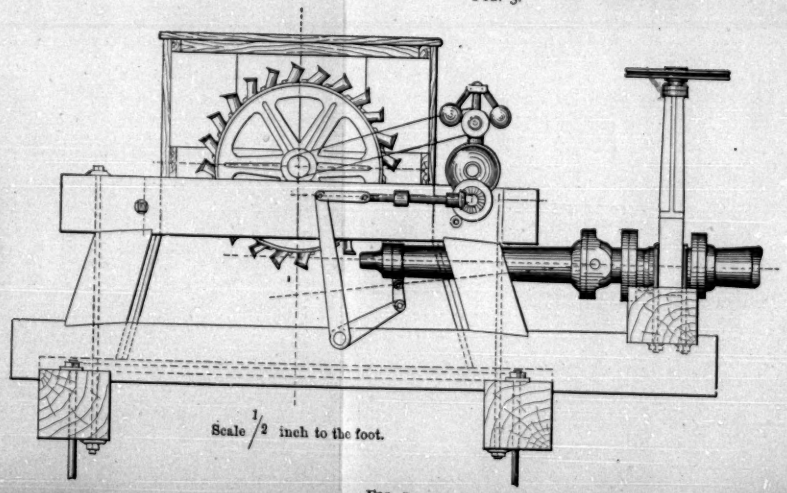


FIG. 7.

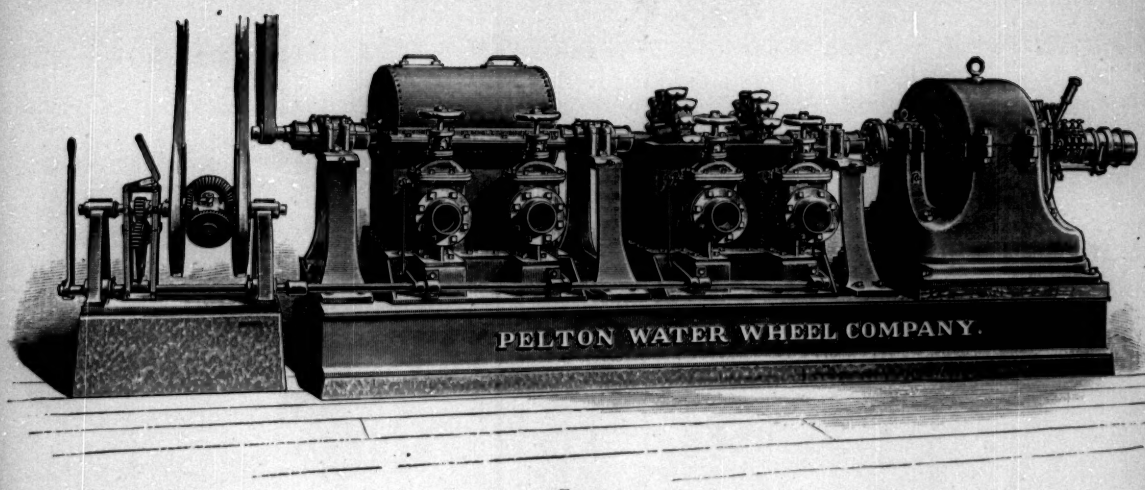


FIG. 4.

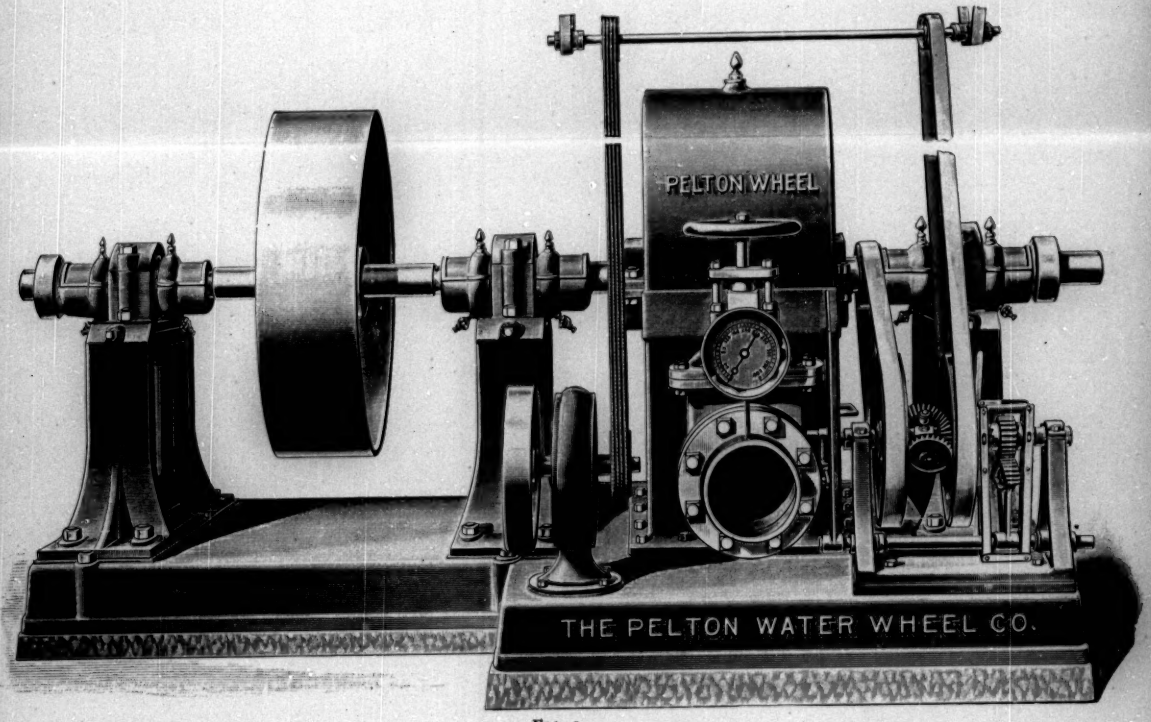


FIG. 9.

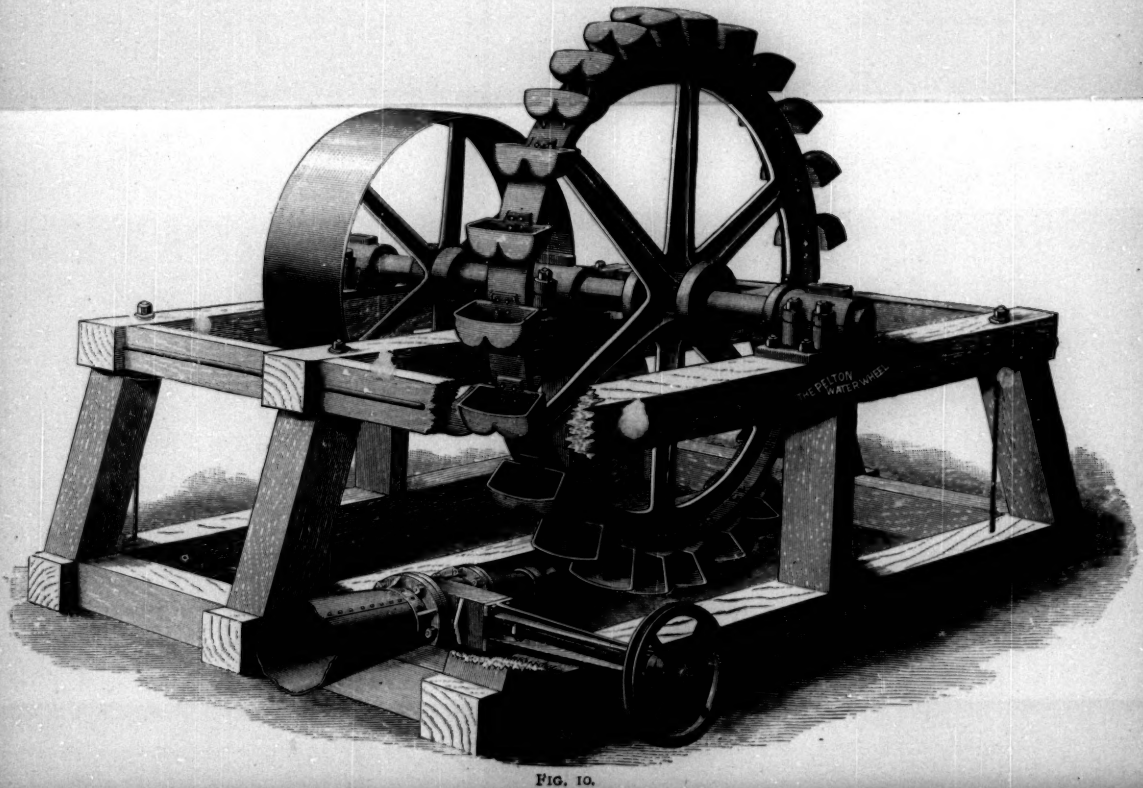


FIG. 10.

possibly breaking something. This method is advantageous in electric lighting, where there is a demand for close governing.

The old method of mounting these wheels has been criticised by some, but it should be remembered that the wheel and its accessories have been developed in the mountains, and have naturally been influenced by the surroundings and conditions of erection and use. The transportation of heavy iron cases on the backs of animals and over bad roads was a serious question, so recourse was had to wooden frames usually constructed on the spot, as shown in *Fig. 10*. They were made of heavy timber, bolted together and boxed in so as to be water-tight. The shaft and nozzle had ample support, and so far as use was concerned, they fulfilled every requirement. In later years iron has come into use very extensively, either cast or in sheets riveted together, making a machine ready for the application of the water. These remarks apply only to the larger wheels, as the small ones have, from the first, been mounted in well-designed cases (see *Fig. 4*, which shows a twin motor with the cover removed).

Nothing contributes so much to the prosperity of mining and manufacturing as cheap power. Scores of the largest producing and most profitable mines on the Pacific Coast could not be worked to-day but for this, as most of our heaviest mining operations are based upon handling a large amount of low-grade ore in a most economical way. Another fact, indicating the change wrought by the introduction of these wheels, is the high price that low-grade mines are commanding, when so situated that water-power can be availed of; these mines, a few years ago, could hardly be given away.

Where the power developed by the wheel cannot be applied directly to the machinery to be operated, electrical transmission can cover the intermediate space, and so in time these easily established links will connect many of the great industrial establishments with these water-powers, now by this wheel made economically available.

That this result has already been accomplished to a much

greater degree than was ever thought possible, is evidenced by the hundreds of mining and other enterprises on the Pacific Coast, as well as in many other parts of the world, that are using this motor profitably.

The remarkable efficiency of the Pelton wheel is a surprise to all who see it in operation for the first time. That a wheel so small as almost to escape observation should be capable of driving the large amount of machinery that is often attached to it, is a perpetual wonder, even to those long accustomed to its use. Nothing but a humming sound is heard; and a little rivulet flowing from it, scarcely more than a thirsty horse would drink, is all that is seen.

Its absolute simplicity of construction, as well as its perfection in mechanical detail, afford the greatest possible security against irregularity in running or necessity of repair. Many have now been in constant use for at least ten years, with little stoppage or wear. In fact, no wear is possible, except with muddy or gritty water. In such case the buckets may need replacing once in two or three years. This, however, involves but little time and small cost. The buckets being open, with a free discharge, are never obstructed by leaves, roots or other foreign matter.

These wheels are made in sizes from four inches in diameter, and weighing, with case, twenty pounds, for driving sewing machines, dental apparatus, and the like, to wheels of five, six, eight, ten and in some cases even twenty feet in diameter. Wheels of such large diameter are not for the purpose of increase of power, but to reduce speed so as to make a direct connection to the shafts of the machinery they are to operate as in the case of pumps, compressors, etc. By applying three, four or five streams to a wheel of ten to fifteen feet in diameter, from 3,000 to 5,000 horsepower can be obtained from a single wheel under a head of 150 feet. This illustrates the extreme flexibility of the system and its application to varying conditions, units of power, speed, etc.

In considering the conditions necessary to a high efficiency in the jet wheel, it will be found that the main conditions are as follows:

(1) The jet should enter the bucket without shock and flow over easy curves until its direction is reversed:

(2) The surface over which the water passes should be small to reduce skin friction:

(3) The speed of the wheel should be such that the water will leave the bucket without velocity.

Prof. Unwin, in an address to the Institution of Civil Engineers, about 1885, stated that:

"About twenty years ago there was introduced a form of impact wheel called the 'Hurdy-Gurdy.' (See *Fig. 11*,

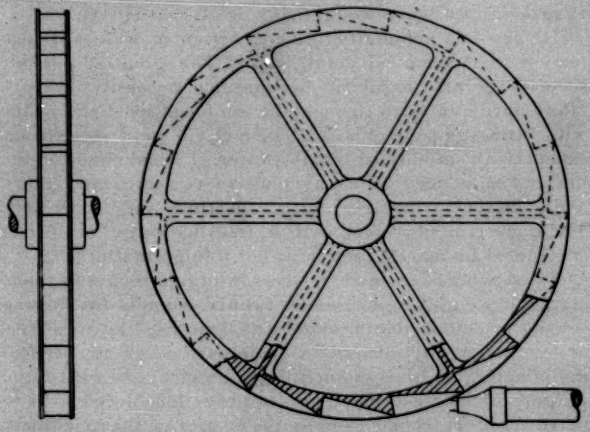

FIG. 11.

which shows a side and front view of a simple form of this wheel, having flat radial vanes. Part of one of the side plates has been cut away, to show more clearly the manner in which the jet of water is received, while the nozzle shows the location of the stream.) It consisted of a wheel of considerable diameter, with a series of cast-iron floats, four to six inches wide on the face. A jet of water was allowed to strike the vanes normally. Theory shows that in this case the wheel should run at half the speed of the

jet, and that the efficiency, even apart from the friction, could not exceed fifty per cent. Practical experience also shows that the wheel should have half the velocity of the jet, and the efficiency was found, by experiment, to be forty per cent. In spite of the low efficiency, such wheels seem to have been useful, partly because they were cheap and free from liability to accident, but mainly probably because by choice of diameter of wheel any convenient speed of rotation can be obtained.

"It is easy to see that the efficiency could be improved by substituting cups for flat floats, and this is what has actually been done. The favorite now is a wheel termed the Pelton wheel, the floats of which are simply cups which

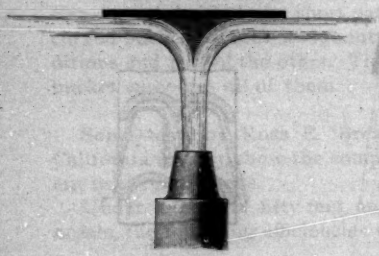

FIG. 12.

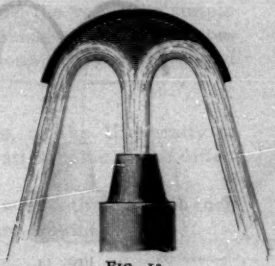

FIG. 13.

deviate the water backwards. I see no reason why, with a very high fall, an efficiency of eighty per cent., at all events, should not be reached."

Professor Merriman says, in discussing the "Energy of a Jet:" "The amount of work which is realized when a jet strikes a moving surface, like the vane of a water motor, depends upon a number of circumstances, and it is the constant aim of inventors so to arrange the conditions that the actual work may be as near to the theoretic energy as possible. Values expressing the efficiency, greater than 0·90, have been obtained."

Statements such as these, coming from the best authorities, give encouragement to those who handle the practical

side of these problems, by showing that high efficiencies are possible.

*Flat Vanes.—Fig. 12* shows the action of a jet of water striking a flat plate at right angles. It will be seen that the water divides and shows a tendency to form a wedge of still water; this is what may be termed "dead" water, that is, water which has lost its impelling force. In a wheel having this form of vane, there is a tendency to form such a wedge on each vane at every revolution; there can be no smooth flowing of the stream, but a continual turbulence, resulting in a loss of energy, and the amount of this will be greater than the loss of part of the energy contained in the water represented by the wedges. It will be seen, also, that the

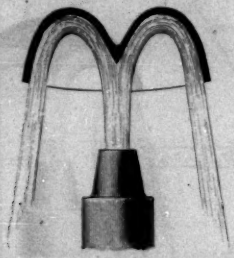

FIG. 14.

FIG. 15.

direction of discharge precludes a complete stoppage of the water, the highest theoretical efficiency being fifty per cent., excluding losses from friction, turbulence, etc.

*Curved Vanes, No Wedges.*—In the simple curved buckets shown in *Fig. 13* will be found the same condition as to wedge formation as was shown on the flat plate, the amount of water so perverted being even greater. There is, however, a reversal of the stream which allows it to be almost completely checked. This is an important advantage, as may be seen in a comparison of the efficiencies obtained.

*Curved Bucket with Wedge.—Fig. 14* shows a third form, in which the wedge has been made a part of the bucket itself, thus avoiding the loss due to the water wedge and to turbulence. *Impact* has been reduced to a minimum, and the

bucket forms part of an *impulse* wheel. This is the Pelton, which has shown a higher efficiency than any other jet wheel, and which is now replacing the older forms.

In wheels having flat radial vanes or buckets, and a tangential application of the stream, the angle of impingement varies as the vanes pass through the jet, but there is at all times an *impact* resulting in a loss. In contrast with this is the *impulse* wheel, in which the water enters the vanes or buckets without shock, and is led in the proper path, there being no coercion of the water, but a smooth, regular flow. In the *impact* wheel there is a *blow struck*, while in the *impulse* there is a push.

It will be seen that the impact wheel or "Hurdy-Gurdy" conforms to only one of the principal requirements for efficiency, namely, that of a short path on the vane; the simple curved bucket without wedge introduces two of those conditions and part of the other. The double curved or wedged bucket embodies all of them.

Some tests by Ross E. Browne, at the University of California in 1883, show the comparative value of the different buckets or vanes.

Under a head of fifty feet, and with a three-eighth inch nozzle, the following efficiencies were obtained:

| | *Per Cent.* |
|---|---|
| Hurdy-Gurdy | 40·4 |
| Bucket without wedge | 65·6 |
| Bucket with wedge | 82·5 |

In explanation of the result obtained by reversing the stream, let the speed of the jet be ten feet per second, then the bucket speed will be five feet per second. It follows that the jet speed in relation to the bucket will be the difference, or five feet per second. When the water is reversed, the jet movement in the bucket is in one direction, while the bucket travels in the opposite direction at the same rate, the result being that the water drops from the wheel without velocity. It is evident that at no speed will it be possible to completely check the water in the flat vane wheel.

It is not possible to completely reverse the stream even in the double curved bucket, the reason of which is shown in *Fig. 15*. Something must be sacrificed in this direction in order that the water may clear the bucket which follows. The angle of deviation will depend upon the distance between adjacent buckets, but in no case should the loss from this cause exceed one per cent.

To make such tests of this wheel as would be convincing and satisfactory, the committee charged with this investigation found to be impracticable. In lieu thereof, the committee has found it necessary to rely upon the corroborative results of tests made by men esteemed by the committee as fully competent to do such work.

In the tests of this wheel made by Mr. Ross E. Browne at the University of California, "the diameter of the wheel was fifteen inches, the width of the bucket 1·5 inch, and the efficiencies shown under fifty-foot head were as follows:

"With a seven-sixteenth-inch nozzle, 82·6 per cent.; with a three-eighth-inch nozzle, 82·5 per cent. The efficiency was determined under as low a head as eight feet, still showing 73 per cent. It is proper to state that the wheel with which the above tests were made was constructed in the workshop of the University, and did not conform wholly to the manufacturer's standard. The size of the bucket was too small to do full justice to the wheel, owing to the difficulty of shaping the curves accurately. It is claimed that tests with larger wheels have given higher efficiencies, and I have no reason for doubting the claim.

"I do not hesitate to express the following opinions regarding the Pelton wheel operated by circular jets:

"(1) It will give a high efficiency under a wide range of heads, say from twenty feet upward:

"(2) It will be equally efficient whether operated by very small or very large nozzles, provided the proper ratio is maintained between the diameter of nozzle and size of bucket, etc.:

"(3) Its general simplicity of construction is a matter of great advantage in its application as a motor. In designing a plant, the size or number of wheels can be more readily

adapted to the requirements of speed, of shafting, and distribution of power, without sacrifice of efficiency or entailment of extravagant cost. It becomes practicable to make more direct applications of the power, frequently enabling the avoidance of counter-shafting, etc.:

"(4) It meets the requirements of a high-head wheel much more efficiently than do the common forms of turbines. It is evidently far better adapted to high heads than the closed or full-running turbine.

"Closed turbines are distinctly *low-head* wheels, and are not efficient motors under high heads. A high velocity of the enclosed wheel of a full running turbine causes great agitation and turbulence of the confined water, and it is readily apparent that there occur extravagant losses by impact. The superior efficiency of the Pelton, as a high-head motor, is due to the high efficiency of the circular nozzle, the smooth and rapid deflection of the water in passing through the open bucket, and the small aggregate amount of wetted surface in the buckets."

A test was made in the Mechanical Department of the University of Michigan, under the direction of Prof. M. E. Cooley.

A twelve-inch wheel was used, the size of the nozzle one-quarter inch to one-half inch, the efficiency obtained was eighty per cent.

These experiments may be regarded as disinterested ones, being made wholly from a scientific standpoint, while the high character of the institutions mentioned afford assurance of accuracy in all details as well as in conclusions.

The adoption of this wheel by a great number of companies is the best evidence of superiority. Referring to one of the manufacturer's printed lists, we find that 840 companies are using these wheels, many of them running from ten to fifteen wheels under heads varying from 18 feet to 2,100 feet.

*Notes Regarding the Operation of the Chollar Plant.*—This station is located at the Sutro Tunnel level of the Chollar

shaft, and consists of six Pelton wheels, forty inches diameter, connected direct to electric generators, the power from which is carried by wire to the surface and operates the California Mill. The wheels are running under a vertical head of 1,640 feet at 900 revolutions, each wheel giving off 125 horse-power, with a nozzle five-eighths of an inch in diameter.

The following statement from the superintendent of the Chollar Mining Company, referring to the electrical plant above described, is given for the purpose of showing the practicability of operating electric generators underground, and also the reliability of a power plant running under such extraordinary conditions:

"As regards the operation of water wheels on the shafts of the dynamos, there is, in my opinion, no better way of running them where the head will admit of such a direct connection. The Pelton wheels attached to the generators in the station at the Sutro Tunnel level of our shaft, have now been in operation for some three years without giving any trouble, and with very little expense in the way of repairs, and they have given entire satisfaction as regards efficiency, regulation and general reliability. As to running generators underground, I consider it quite as feasible as operating them on the surface; and if I were going to run another plant under similar conditions, I should use Pelton wheels attached to the shafts of the generators, as in the present case, believing it to be the most efficient and economical method of producing power.

"Many of these wheels have been in constant service for several years, with no trouble whatever, and with practically no expense in the way of repair. Though running under such extraordinary conditions they are still in perfect order, and good for an indefinite period of service. The Pelton wheel is equally adapted to moderately low heads, say from twenty feet upwards, it being in any case simply a question of adaptation of nozzles and buckets to water available, head and power requirement."

It may be of interest to refer briefly to some predecessors of the wheel under consideration.

The Roman architect and engineer, Vitruvius, about 14 B. C., figures and describes water mills, in which the millstones are turned by a current-driven wheel, shown at *C* in *Fig. 16*, the same having flat, radial vanes, against which the water acts in its flow down-stream. Upon the horizontal axis of this wheel is a toothed *tympanum B*, geared into and

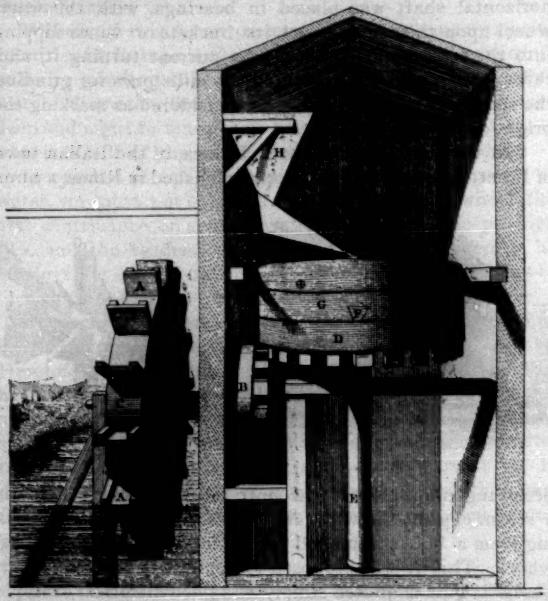


FIG. 16.

set to turn the larger horizontal *tympanum D*, secured to the vertical shaft *E*, "having at its upper end an iron dove-tail *F*, which is inserted in the millstone *G;* thus the teeth of the tympanum *B*, that is included on the axis, impelling the teeth of the horizontal tympanum *D*, cause the rotation of the millstone to which the suspended hopper *H* furnishes the grain, and by the same rotation the meal is ejected."

Later on, when Rome was besieged (A. D. 537), the supply of water from the aqueducts which fed the canals being cut off, Belisarius placed boats on the Tiber, and upon them erected mills.

These consisted of two boats moored in the stream, say two feet apart, and across this space, from boat to boat, a horizontal shaft was placed in bearings, with the water wheel upon the central part, its buckets or vanes dipping into the stream, the force of the current turning it, and, through proper gearing, turning the millstones for grinding the corn. This episode may be considered as marking the origin of "floating mills."

"In the year 1629, Giovanni Branca, of the Italian town of Loretto, described, in a work published in Rome, a num-

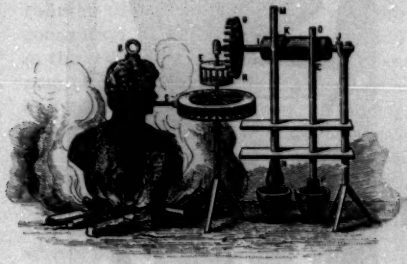

FIG. 17.

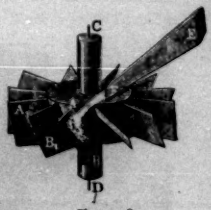


FIG. 18.

ber of ingenious mechanical contrivances, among which was a steam engine, shown in *Fig. 17*, in which the steam issuing from a boiler impinged upon the vanes of a horizontal wheel. This it was proposed to apply to many useful purposes." This is quoted simply as a good historical example of the invention and application of the jet to the propulsion of wheels.

One of the early forms of "impact" turbines is shown in *Fig. 18;* this is the simplest, but also the least efficient form of the impact wheel.

It consists of sixteen to twenty rectangular floats or vanes, *A B*, set upon the wheel so as to incline 50° to 70° to the horizon.

The water is laid on by a pyramidal trough, *E F*, inclined from 40° to 20°, so that the water impinges nearly at right angles to the floats.

Such wheels are employed for falls of from ten to twenty feet, when a great number of revolutions is desired, and when simplicity of construction is a greater desideratum than efficiency.

Wheels of this form are met with in all mountainous countries of Europe, and in the north of Africa, applied as mills for grinding corn. They are made from three to five feet in diameter, the buckets being about fifteen inches deep and eight to ten inches long. The efficiency of these wheels is half of the entire mechanical effect available.

In our list of early devices for obtaining the power of water, we must not overlook the familiar flutter wheel, the first contrivance of every boy who has hydraulic proclivities, and the readiest resort of the colonist, whereby he employs the dash of the neighboring mountain streams to turn the crank of his primitive saw-mill.

Economic considerations must in the future compel a wide use of the tangential jet wheels in this country. Heretofore the settlement of the country and its industries have been confined to flat lands, where the head of water available was suitable only for turbine wheels. Now that successful means of transmission exist, and various industries, especially mining, are extensively carried on in districts where the heads of water are great and the quantity small, jet wheels must take a prominent place among prime movers.

The committee charged with this work has been requested to consider the water wheel of Mr. Jearum Atkins. It will be sufficient here to repeat and analyse his claims, filed in the United States Patent Office, February 27, 1853, and which will enable us to understand the meaning and scope of what he proposed to do. His patent was not issued until August 10, 1875.

"*Claim 1.*—The mode of constructing water wheels with buckets placed longitudinally with the wheel's axis, with

semicircular water passages between them in combination with a water-trunk, so formed and proportioned as to cause the water to act continually upon all the buckets of the wheel.

"*Claim 2.*—The mode of constructing water wheels and apparatus connected therewith, so as to cause the water to impart its velocity, and consequently its power, to the wheels, by describing a half-rotary motion against semicircular-shaped buckets, formed and arranged in the manner set forth."

The words of this first claim, interpreted by the drawing and specification, clearly define semicircular waterways in the wheel, which are not only of even width and area throughout, but are also parallel with the axis of the wheel, and that the water supplied to a properly formed trunk surrounding the wheels acts upon all the buckets simultaneously.

Particular stress is placed upon the relative areas of the waterways to and through the wheel, the latter being made double the former, in order that the water in the wheel, as well as the wheel itself, may go at half the speed of the entering water; and since the motion of the water is reversed by the semicircular buckets, it leaves the wheel without velocity, and must therefore give up all its energy to the wheel.

The particular form of wheel disclosed by Mr. Atkins' first claim appears to have been new at that date, and he is entitled to credit accordingly, but as the investigating committee had no means of knowing the percentage of useful effect that was given by this wheel, by which the commercial value of a motor is determined, no estimate can be formed of the value of the Atkins wheel as compared with others in use.

It is to be regretted that Mr. Atkins was unable to prove, by test, the superiority of his wheel, and the most that the committee can do is to show what novelty there is in his proposition, in so far as his patent discloses his invention.

Considering this wheel, and the history of wheels, in detail, we find that the first current and jet wheels, and nearly all the under- and overshot and breast wheels, and

some of the turbines, built prior to the Atkins invention, have their buckets parallel to the axes of their wheels.

The following references also will be found pertinent to the case:

Poncelet, in 1827;
Madame de Girard, 1843;
Zuppinger, 1845;
De Canson, 1847.

Surrounding water trunks of various forms and capacities have been furnished to nearly all the turbines, from their first inception, in which special provision is made for the water to approach all the buckets freely and at once.

The records show semicircular waterways to be much less numerous than quarter-turn ways, which latter favor and secure the full force of impact, as well as the reactive effect of the water; in all these cases, however, the water makes a half-circle turn, being reversed in direction as it leaves the wheel, from the direction in which it enters.

This feature may be regarded as essential to the perfect waterway. It is embodied in all high-class wheels, and it is remarkable that this principle of action was conceived and formulated by that eminent mathematician, Euler, about the year 1750.

The Fontaine wheel, as at present constructed, is the nearest embodiment of his conception. This construction may be made clear by a few words: From a superposed enclosure the water enters curved guideways vertically, and is delivered horizontally and normally against all the curved wheel vanes at once, from which it finally issues in a horizontal direction.

This action of the water gives the wheel the full force of its impact as it enters, and of its reaction as it leaves the wheel, the water making a half-circle turn in its passage through the wheel.

It is fair to assume that every turbine wheel maker aims to secure this result; for by that act he catches and holds the water in the hollows of his wheel vanes till it gives up all its living force and then lets it drop speedless from the wheel.

The broadest interpretation that can be put upon Mr. Atkins' second claim would embody the idea of the half-circle turn made by the water in its passage through the wheel.

Poncelet, in the year 1827, was perhaps the first to call attention to and prove the loss of effect by the dash of the water against flat-faced vanes set normal to its course. For these he substituted curved forms, concave and tangent to the entering current, so that the water is continually running up concave inclines and running back again, permitting the water all the while to impart its energy to the wheel. Of this scheme it may be said: "The Poncelet float conspicuously demonstrates the essential importance of providing graduated entrances and avoiding shocks, concussions, or eddies in the water."

Here we have the fact well established that in order to secure higher results the water must both enter and leave the wheel in lines tangent to the course of the buckets.

In the wheel of James White, prior to the year 1822, will be found evidences of semicircular buckets and water inlets to them of lessened areas, all the water escaping in the same direction as that of the wheel; all the buckets are acted upon at once, and the floats are given "the most perfect form for receiving the utmost impulse from flowing water."

The wheel of Madame de Girard, Paris, 1843, has half-circle buckets, the water entering from beneath in a volute, and escaping all around outwardly.

In de Cansou's French patent of 1847, with either horizontal or vertical shaft, "the water was directed against the lower blades from the interior by a simple pipe with a single orifice, opened more or less by a small vertical sluice." These buckets were quarter-circles, the jet striking them normally, the water escaping from the wheel tangentially.

Girard's wheel is upon a horizontal shaft, having two bearings, the water supplied through a nozzle covering a small part of the internal circumference of the ring of the buckets, the spent water escaping outwardly into an annular case surrounding the wheel.

The buckets are semicircular and parallel to the shaft. These wheels gave seventy-five to eighty per cent. of useful effect, a maximum of eighty-seven per cent. being recorded.

Even in the Whitelaw & Stirrat wheel, based upon the principle of the well-known Barker's mill (first observed by Bernoulli in 1730, and constructed by Segner in 1740), and which utilizes the reactive force only of the water, according to the best method of laying out the curves of the radiating arms, the central path of the water from the flume to its final escape into the atmosphere, is a semicircle.

In the United States patent of L. D. Goodwin, April 4, 1854, we find the following words in his claim: "The form and proportion of the buckets are specifically set forth, commencing in a true circle at a tangent to the outer periphery, and terminating in a straight line, fifteen degrees in length, at the inner curve, and in a tangent thereto." The water is admitted to all the buckets at once from a surrounding volute; the buckets are parallel to the axis of the wheel.

The subject is a complex one, presenting many forms of guideways and buckets, and numerous directions of waterflow to and from the wheels. Of course, all these are liable to cover one another in part and to present strong resemblance in detail, but nowhere do we find the exact counterpart of the Atkins wheel, nor any likeness to the Pelton.

In view of these earlier actualities of invention, surely Mr. Atkins can neither claim *broadly* the semicircular bucket for waterway through his wheel, nor the conception of the idea that the water should enter the wheel without shock and turbulence, and leave it without velocity or living force, describing a half-circle through the wheel to secure this result.

The semicircular bucket, as described by him, for the purposes named is, so far as we know, his invention, but no such construction exists in the Pelton wheel, nor does Mr. Pelton make claim for it, nor do we find on record even a hint of a divided bucket in any way resembling the Pelton type.

From all that has preceded, the conclusion is reached that the Pelton water wheel possesses all the advantages

of simplicity of construction, economy of installation and maintenance, adaptability to extreme heads of water, of transportability, of close and sensitive automatic regulation and of high speeds, which belong to other wheels of its class which have preceded it, but that in point of efficiency, it has excelled all others.

The Institute, therefore, deems the Pelton water wheel worthy of the Elliott Cresson Medal, and hereby awards the same to Lester A. Pelton, the inventor of this wheel.

*Adopted* at the stated meeting of the Committee on Science and the Arts, held Wednesday, February 6, 1895.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
SAMUEL SARTAIN, *Chairman.*

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## APPENDIX.

[*Historical notes and data having reference to the foregoing report.*]

COMPILED AND EDITED BY JOHN H. COOPER, Chairman of the Sub-Committee.

The object of this Appendix is to present more in detail the data, dates and authorities relating to the curved buckets of water-wheels.

Since water-powers are coming to the front now for treatment, whatever light can be thrown upon the philosophy and construction of hydraulic motors must have immediate and commercial value.

A glance at German, French and English literature has revealed to the writer an elaborate and extended chain of valuable historic precedent, of which a few links are here given, although in a somewhat disjointed array.

As early as the year 1744, Desaguliers said that a wheel of large diameter, as an overshot, may go with less water, if the water be applied to the wheel without any percussion.

Bernoulli recognized the loss of efficiency when the water leaves the wheel, and, soon after, Euler recognized the loss by impact. Borda, in his "Mémoire sur les Roues Hydrauliques," in 1767, announced the proposition in precise and general terms, whence he concluded that, to produce its total mechanical effect, the water serving as moving power must be brought onto the wheel with impulse, and quit it without velocity.

Atkins' second claim, embodying the idea of the water imparting velocity and power to wheels "by describing a half-rotary motion against semicircular buckets," * * * is a very sweeping one, and would cover broad ground if it were not limited to the construction specified.

The motion of water in a semicircle, while imparting power during its passage through a wheel, is as old as the first constructed turbine, which, so far as we have been able to raise the veil of history, dates with Euler's declaration of it in the year 1754.

An ideal elevation of the guides and buckets of an Eulerian wheel is given in *Fig. 19*. By following the water through the wheel, a half-circle motion will be indicated.* But the first introduction of Euler's idea to actual service was by Fontaine, prior to the year 1840. Our *Fig. 20*, taken from Dingler's *Polyt. Journal*, 1858, gives the forms of the waterways, which plainly appear to be well-nigh in conformity with a half-circle motion of the water while driving the wheel. Now we know that Euler was aware of the loss of efficiency by impact, and that a backward initial curving of the buckets was added later by many builders of wheels, thus securing the impulsive action of the water.

From "Belidor's Hydraulic Architecture," New Edition, by Navier, Paris, 1819 (see also "Encyclopédie des Sciences," Neufchatel, 1765), we transcribe as follows:

"In Provence and a considerable portion of the Dauphiny, the mills are of extreme simplicity of construction, consisting of only one horizontal

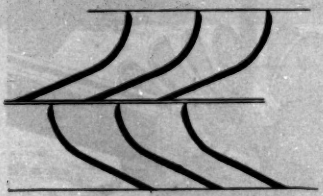


FIG. 19.

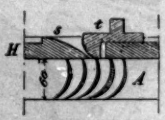



FIG. 20.

wheel, *D* (*Fig. 21*) from six to seven feet in diameter, of which the buckets are spoon-shaped in order to receive the stroke of the water which is delivered ordinarily through an inclined trough.

"The spindle *E*, which engages with the upper stone, is the only piece employed to communicate motion thereto. * * * The wheel rotates upon a pivot within a socket formed in the centre of the transverse brace of the frame *O F*, which serves to regulate the distance between the two millstones by means of a screw. * * * The wheels which one sees manufactured in the style of this one, have their spoon-shaped arms assembled to the spindle, simply by a tenon and dowel pin; they are reinforced from beneath by means of brackets which maintain them all uniformly. * * *

"Others are constructed as shown in plan view *M* (*Fig. 22*) and its transverse section *N*, which a single inspection will render sufficiently comprehensible without further explanation."

Coming now to a type of wheel more nearly resembling modern constructions we quote further:

"It appears, in fact, that the remarkable disposition of the water wheels

* Fourneyron began his studies of the turbine in the year 1823, and erected his first wheel in France in 1827.

at Basacle (in the vicinity of Toulouse) is that which Borda had in view in the theory which he has given of a particular kind of horizontal wheel with curved pallets. (Academie des Sciences, 1767.) Referring to (*Fig. 23*) *M N* is the horizontal wheel in question, taking for instance a wheel furnished with curved blades such as *C D*, and that water directed by a tube *B C* is introduced between the pallets tangentially to their curvatures, and flows off at their lower extremity *D*, towards *E*.

"The theory very properly indicates the manner in which wheels of this style should be arranged, in showing that the only object in view is to regulate the movement in such wise that the water shall leave the wheel with no

FIG. 21.

velocity, and therefore imparts to the wheel the entire momentum which it might have acquired in passing freely through the entire course of its fall.

"The theory also supposes essentially that the water, in entering the wheel at *C*, experiences no shock. This condition is filled by giving to the tangent of the curve of the bucket at *C*, the direction of the movement of the water at the instant when it commences to run along said bucket.

"In representing by *BC* the velocity $\sqrt{2gh}$ of the water when it arrives at *C*, and by *BF* the velocity, *V*, of the wheel, the line *FC* will represent, in length and in direction, the velocity with which water commences to pour into

the wheel, and, in consequence, the first element of the curve of the bucket at $C$ must be in the direction of this line.

"The curvature of this bucket is indeed indifferent, provided it offers no angular bends, and that the direction of the tangent at the point $D$ of exit of the water be as nearly horizontal as possible, without interfering with the discharge of the water.

"It will always be desirable to give to the vein of water and to the buckets only slight width in the direction of the radius of the wheel, because as the speed of rotation is not the same for the points at different distances from the axis of rotation, there is never but one point of the bucket which can have a speed capable of giving the maximum effect.

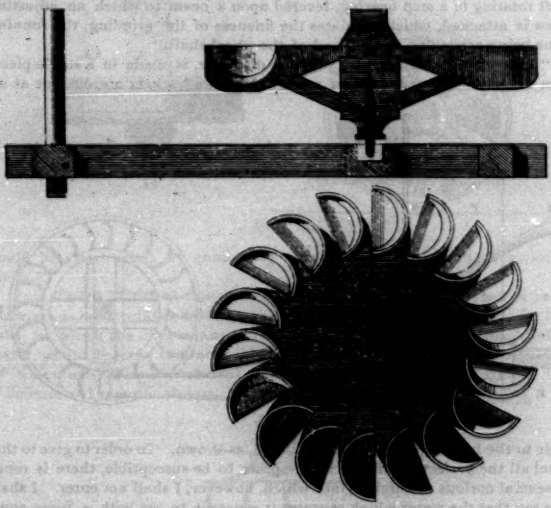


FIG. 22.

"If one had a large quantity of water, it could be caused to arrive by several tubes or inclined inlets distributed around the periphery of the wheel in vertical planes tangent to its circumference.

"One could, also, as Euler proposed in 1754, receive the water in a cylindrical vessel, having a diameter equal to that of the wheel, placed vertically above the same, and through which the shaft of this wheel would pass, and from which the water would escape by a number of inclined ajutages distributed at the circumference of the cylinder.

"Of all the water wheels which have been invented heretofore, I do not believe that there are any that show more ingenuity or more simplicity than

those which have been installed at Basacle, where there are twenty-five pairs of grindstones in line, each driven by a water-wheel, singly and similarly operated, and which maintain the flour supply of the city and suburbs."

These wheels are shown in plan and elevation in *Fig. 24*. They were surrounded by a cylindrical flume, to which the water was supplied tangentially, forming a whirlpool, and constraining the horizontal wheel which forms the bottom of the forebay to rotate with it. "The water which has entered into the forebay, after having previously effected several gyrations, and struck the buckets of the wheel, passes through the openings which exist between the said buckets, and escapes on the discharge side or tail-race, which is downwardly inclined. The wheel is mounted upon a square shaft rotating in a step bearing, levered upon a beam to which an adjusting screw is attached, which regulates the fineness of the grinding, the running stone being carried on the top end of the wheel shaft."

"This wheel, which is only 3 feet in diameter, is made in a single piece, from the section of the trunk of a large tree; the buckets are cut out at an

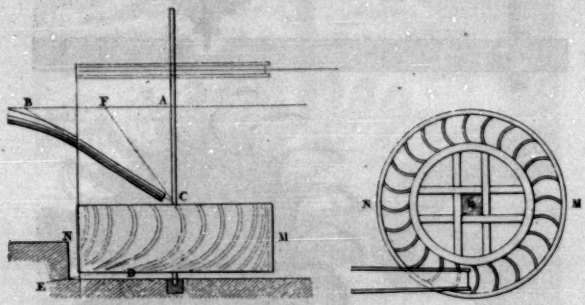



FIG. 23.

angle to the horizon, being slightly curved, as shown. In order to give to this wheel all the perfection of which it appears to be susceptible, there is room for several curious researches, into which, however, I shall not enter. I shall only say that the water which operates it causes it to act with a force composed of the action of its weight, and of the circular direction imparted to it by the cylindrical forebay, and that the curvature of the buckets should follow that of the development of a circle."

In the American edition of "Ferguson's Lectures," 1806, a description and cut are given of an undershot wheel having buckets inclined to the radius: "It is driven partly by the impulse, but chiefly by the weight, of the water; the 'mill course' descends to and directs the water into the wheel nearly in line with the buckets, which insures the impulsive action of the water." (See also *Dict. des. Sci.*, Paris, 1767, pl. vii, an undershot wheel with inclined buckets.) M. Lambert, of the Academy of Sciences, at Berlin, 1775, indicates the angle at which the floatboards should be placed. These

references show the tendencies of construction at that time toward favoring the impulsive action of the water as it enters the wheel.

Navier's notes on "Belidor's Hydraulic Architecture," published, 1819, p. 461, § 4, confirms the above in the following quotation: "The necessity of disposing machines in such wise that there should be no shock, although established long ago, both by theory and practice, is not so generally recognized as could be desired. * * * Mr. Brewster also announces that he has frequently had the idea that a hydraulic machine of great efficiency

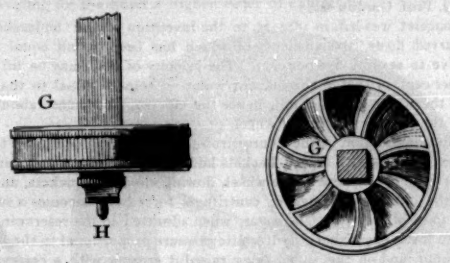



FIG. 24.

could be constructed by combining the impulsion with the reaction of water."

Zuppinger's so-called tangent wheel was one of the first types of radial outward- as well as inward-flow impulse turbines, intended to be used for high falls, for which the dimensions of reaction turbines, obliged to work full of water, would become impracticably small, "* * * such that the quantity of water used is only sufficient to act upon a few vanes at a time." (See "Bodmer's Hydraulic Motors," p. 39.)

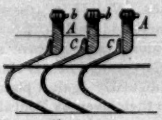



FIG. 25.

The curve of the buckets and the lines of water admission are fairly shown by Chenevals' turbine, in *Fig. 25*, copied from Dingler's *Polytech. Jour.* for 1857. (This figure may also represent the buckets of the Poncelet Turbine, for which see *Fig. 283*, Johnson's "Weisbach," 1849, p. 296.)

Vertical tangential wheels with outward flow were first constructed by Schwamkrug prior to 1850. (For this see Du Bois' "Weisbach," *Fig. 468*, p. 367, in which the buckets and guides are also well shown by *Fig. 25*.) The curved bucket for the initial tangential action of the water is very apparent in all these cases.

From Rees' Cyclopedia, American edition, 1810-24: "The Chevalier de Borda observes that in theory a double effect is produced when the float-boards are concave, but that the effect is diminished in practice, from the difficulty of making the fluid enter and leave the curve in a proper direction. Notwithstanding this difficulty, however, and other defects which might be pointed out, horizontal wheels with concave float-boards are always superior to those in which the float-boards have plain surfaces."

At the meeting of the Institution of Civil Engineers, London, for March 22, 1842, Prof. Gordon said:

"Poncelet was led, in 1824-25, to the invention of the 'undershot wheel with curved floats,' the efficiency of which has been found equal to from sixty-five to seventy-five per cent. The velocity of this may be fifty-five to sixty per cent. of that of the effluent water—a velocity equal to that due to nearly the whole height of fall; hence the efficiency becomes 'about double that of the ordinary undershot wheel.'

"The construction of the Fourneyron turbine may be compared to one of Poncelet's wheels with curved buckets laid on its side, the water being made to enter from the interior of the wheel, flowing along the buckets, and escaping at the outer circumference; centrifugal force here becomes a substitute for the force of gravity. The water, when admitted to the reservoir, rises to a certain level, exercising a hydrostatic pressure proportional to the height of the column, and on the sluice being raised it escapes with a corresponding velocity in the direction of the tangent to the last element of the guide curves, which is tangent to the first element of the curved buckets. The water pressing without shock upon the buckets at every point of the inner periphery, causes the wheel to revolve, then passes along the buckets, and escapes at every point of the outer periphery.

"M. Poncelet, in his lectures at Metz, had given, in 1826, a description and theory of a wheel with curved buckets and a vertical axis, analagous to his wheel of the same species of which the axis is horizontal, and which received the water without shock through many points of its exterior circumference, and allowed it to escape without velocity through the interior."

From DuBois' "Weisbach," Vol. II, p. 316, we quote: "When the floats of undershot wheels are curved in such a manner that the entering jet of water is allowed to flow along their concave sides and press against them without causing any shock, a greater effect is obtained than when the water strikes more or less perpendicularly against plain floats. Such wheels with curved floats are called after their inventor, Poncelet's wheels. * * * (*Fig. 26.*) To obtain as great an effect as possible with one of Poncelet's wheels, it is necessary that the water should enter the wheel without any shock. * * * "The water ascends the float like a solid body, with decreasing velocity, while at the same time it has the velocity of revolution of the float. Having attained a certain height, it has lost all its relative velocity, and now falls down along the float with accelerated motion, so that at last it arrives again at the outer end of the float, with the same velocity with which it began to ascend.

"Poncelet himself experimented upon the performances of these wheels, the records of which were made in a special work published in Metz in 1827.

"'The Poncelet wheel (says 'Bjorling,' p. 24) is classed by some authorities under the head of turbines, because they are actuated by the force due to the

rapidity of the current of water and the impulse due to the head and fall combined. The water is admitted down an incline of one in ten, on a curved race, so as to enter the wheel without any shock.' The first idea of an inward-flow tangential wheel is due to Poncelet.

"The object of the curved approach-way for the water, in the Poncelet wheel, is to lay the whole of it onto the wheel without impact, and not the top and bottom strata only; since in these wheels, in order 'to obtain the maximum efficiency, the water must go onto the buckets without impact,' thus providing for the water a higher order of contact."

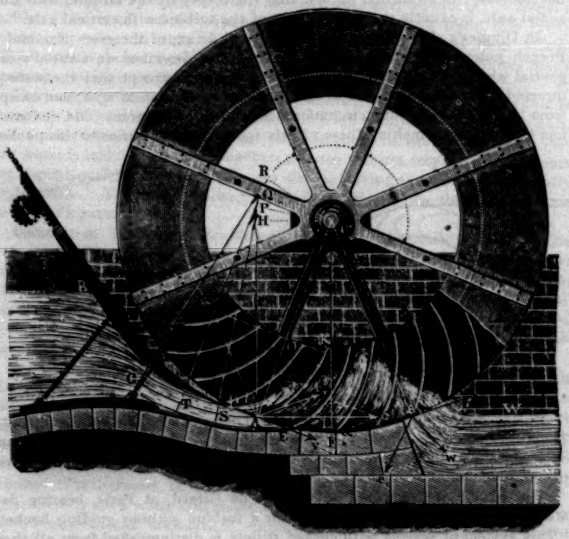



FIG. 26.

In the French patent of M. Callon, October 19, 1840, No. 7,878, the following statements are made:

"These general equations (algebraic) apply, without exception, to all wheels with vertical axes in which the water arrives with a certain velocity and in any direction, and acts by moving itself upon the floats, or in the canals fixed to this wheel. They express that the water enters without shock into the wheel and goes out without velocity. Simplifying these equations they become identical with those given by Navier, and which relate principally to wheels, whether they receive the water upon only one point of their circumference, or receive it at the same time upon the whole circumference, a dispo-

sition which was proposed for the first time by Euler in the year 1754, and which, consequently, is in the public domain. * * * In order that the conditions of the movement of a turbine be as advantageous, and, at the same time, as simple as possible, there must be no shock, and, consequently, no disturbance in the movement of the water.

"It is well understood that the inclination of the guides, or, more broadly, the inclination of the canal which brings the water, relatively, to the axis of the wheel, and the inclination of the first element of the buckets or blades, shall be so combined as to avoid all shock at the entrance." * * * "It is not necessary to go further to see that the theory of the turbine, with horizontal axle, is exactly the same as that of the turbine with vertical axle."

In Dingler's *Polytechnisches Journal*, vol. cxxv, of the year 1842, and in French patent, No. 2,909, 1847, is pictured and described de Canson's tangential wheel. It is somewhat like Fourneyron's, except that the water is directed upon the inner ends of the buckets in the form of a jet, and escapes from the wheel at its outer circumference tangentially thereto. Mr. de Canson had been engaged making these wheels for a long time prior to this publica-

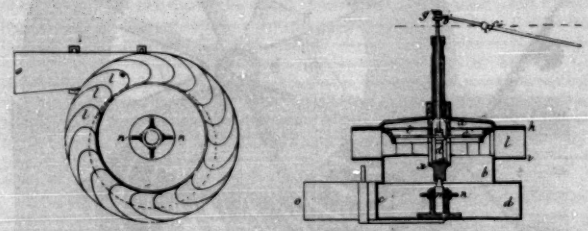


FIG. 27.

tion. He called them *rural turbines*, on account of their great simplicity. They were made to suit any fall of water, from $\frac{1}{10}$ of a meter to 6 meters and over, and gave, under proper working conditions, an efficiency of sixty-seven per cent.

The patent of the wheel of Madame de Girard, at Paris, bearing date March 8, 1843, and number 7,798, is for a turbine without guiding buckets. "This system of wheels with curved pallets is distinguished from all those already known, in that the water, acting from the inside to the outside, arrives between the blades in a direction tangent to the interior of the wheel, without having recourse to the guiding buckets by means of which in the Fourneyron turbines the fluid is given a direction more or less approaching to the tangent.

"We attain this result more exactly still by giving to the passages between the buckets, *l*, *l*, *l*, in the crown, or running wheel, a double curve, in such wise that the water, entering without shock in the direction tangential to the helix, which it follows necessarily, in leaving the cylinder, shall be brought back by a continuous curve in a horizontal direction. (See *Fig. 27.*)

"In order to regulate the ascent of the gyrating water we give to the

bottom of the cylinder a helicoidal form, such that the height of the first turn of this helix shall be equal to the height of the interior opening of the inlet, as indicated by the dotted line" in plan of *Fig. 27*.

Regarding this invenion, it is safe to say that, the principle involved in the semicircular form of buckets permitting the tangential entrance of the water in one direction and its discharge tangentially in the reverse direction, was so well known and understood in the art at the time, that no claim is based thereon, and no mention is made in the patent beyond the facts quoted.

From *Dingler's Polytech. Jour.*, for 1843, vol. xcv, we quote: "Nagel's turbine is a wheel of the Fourneyron type, but differs from this justly celebrated motor in that the water approaches the wheel from below. This, however, is not new, as Mr. Wedding, of Berlin, made turbines many years ago, into which the water was directed upwards to the wheel."

The most important feature to which we desire to call attention, is the double curvature of the buckets in the wheel, which are parallel to the wheel's axis, and are so formed that the guides join with them in easy curves, such that the water is laid upon all the buckets at once without impact, and reverses the direction of its motion within the wheel, leaving the wheel tangentially to its course. The shape of the buckets is identical with those of Madame de Girard's patent.

Bodmer, in his *Hydraulic Motors*, 1889, p. 41, informs us that: "The French engineers, Callon and Girard, commenced in 1856 to design impulse turbines for all possible conditions, high and low falls, large and small quantities of water. These turbines were made both axial and radial, with horizontal, vertical and inclined axes. The impulse turbine has, in consequence, become associated with the name of Girard, and every variety of impulse turbine now goes by the name of a 'Girard' turbine."

Mr. Atkins' first application for United States patent was in 1853, which places him in this line of invention ahead of M. Girard. What happened in these particulars during the century preceding Atkins' invention, this appendix fully sets forth. But inasmuch as every point in the Atkins patent, with which the Pelton invention might be construed to conflict, was known and used before Atkins' time, we have no need of instituting comparisons in this inquiry. Furthermore, in the allowed patent of Atkins, dated August 10, 1875, there is not a word said about the impulsive action of the water upon the wheel, or of the necessity of employing such action in order to obtain better results.

The only claim in this patent which, by construction, as shown on the drawings, would secure the impulsive action of the water, is restricted to a combination of the chutes, which direct the water on to the wheel, with the buckets of the wheel having circular passages of uniform width and an area of water-way double that of the chutes.

Referring to impulse turbines of the Girard and like types of wheels, Bodmer cautions against the liability of choking in the buckets, especially towards their outlets, where there is the greatest risk of this occurring. He also refers to the loss of energy during partial admission of the water, "owing to the fact that a portion of the stream on entering a bucket does not come into contact with the upper end of the same, but impinges on the latter much

lower down, the result being a sudden instead of a gradual change of direction and consequent shock."

These effects cannot happen in the Pelton wheel, because, by construction, the jet is always directed towards the edge of the wedge, forming the initial surfaces of the bucket's curvature, and cannot *begin* to act at any other place. The other defect referred to, to which impulse turbines are liable, except with finer bucket pitches, is impossible of occurrence in the Pelton wheel, because the discharging edges of the buckets, far from being confined in area by adjacent buckets, always give an unobstructed discharge.

In Armengaud's *Pub. Industrielle* for the years 1874–'78–'79–'82–'85 and '86, will be found figured and described a variety of wheels, in which the water is laid on to and received by their buckets in a direction tangential to the motion of the wheels. The water inlets are single and multiple, with means of area regulation; some have straight and some curved guide waterways; all of them have curved wheel buckets, which more or less approach a semicircle in form. *Figs. 20* and *25* may be referred to as giving in general the form and disposition of their waterways.

"Schiele's turbine is a double one, with curved buckets starting from a central midrib. The water is conducted to the wheel in a spiral chamber surrounding it, from which it is guided through narrow ports onto the middle of the wheel's circumference, in such direction as to enter equally the upper and lower buckets of the wheel without shock or turbulence, giving its power to the wheel by a steady pressure while passing along the curved buckets, and issuing from both sides of the wheel to the tail-race, quietly and silently—a clear proof that the whole of the power has been absorbed.

"In thus acting toward *both* sides of the wheel when the same is horizontal, the water exerts no pressure whatever on the foot-step. The wheel is so proportioned that more water is directed to the upper half, and thus balances the weight of the wheel and its attached parts." (See *Prac. Mech. Jour.*, vol. vi, 1861.)

This turbine is noted, because it is the only one found possessing any resemblance to a Pelton water wheel, but since it is surrounded by a water-trunk applying the water to all the buckets at once, and is not adapted to receiving it from a single jet, we do not deem it an anticipatory reference.

To find all the data relating to any particular detail of a water wheel is not an easy task. The following will explain. Mr. James B. Francis, in the year 1855, in his "Hydraulic Experiments" says: "* * * it was said several years previously that not less than 300 United States patents have been granted for reaction wheels and improvements upon them; they continue to be the subject of almost innumerable modifications. Within a few years there has been a manifest improvement in them, giving a useful effect approaching sixty per cent. of the power expended."

The main difficulties with turbines lie in their construction, and these, it is said, M. Fourneyron overcame by long experience, the secrets of which he kept to himself during many years. If we add to these statements another fact—"the records of the earlier turbines are locked up from many readers in a foreign language"—the obstacles which lie in the way of a thorough inquiry into even the leading elements of the theory and practice of hydraulic motors will be found to be well-nigh insurmountable.

The preponderance of testimony here given favors the increased efficiency of wheels with buckets having double curvature. We may therefore, offer the converse and equivalent of this as expressed in Mr. Ellwood Morris' conclusion, in *Jour. Frank. Inst.* for 1843: "To satisfy the condition of maximum effect in hydraulic motors, the water should enter and act upon the wheel without shock and escape from the wheel without velocity."

In order, therefore, to get the advantage here declared, a wheel must have buckets approximating the half-circle form, a construction long in the public domain, and which could not, therefore, properly be claimed as new in the latter half of this century.

The devices for securing high efficiencies are multitudinous along the path of turbine achievement, and on "the principle that their commonness shows their usefulness," as was said, by Desaguliers, in 1744, it seems amazing as we come to know, in retrospect, the inventions of the past, that perfection was not reached long ago.

To have brought a jet wheel to a working efficiency of eighty-six per cent. and over—making it rank with the best and most elaborately designed and constructed turbines—is certainly, therefore a remarkable feat accomplished in hydraulic engineering.

The impulse of water as a method of transferring the living force of a moving liquid to a wheel is an important inquiry in this connection, and we have shown it to be an ancient invention, as compared with a live patent; but our business is not so much to demonstrate the principle of impulsive action, as to exhibit the devices for securing effects; to show plainly the means that have been employed to get the most work out of a given head and quantity of water; that is, the wheel itself. It is the invention of Pelton, not a claim for the principle of impulsion, upon which we are to report.

In conclusion the following efficiency tests are added:

Mr. Ross E. Browne says: "In experimenting with the 'curved buckets,' the efficiency might possibly have been raised two or three per cent. by attending more carefully to the curve and to the size nozzle used. Still there was probably a gain of more than twelve per cent. due to the introduction of the wedge in the Pelton bucket.

* * * "In the year 1884, the proprietors of the Idaho mine, near Grass Valley, Cal., having determined to introduce water-power in the place of steam, invited all the water-wheel dealers and manufacturers on the Pacific Coast to make a public test with reference to determining the efficiency and adaptation of the various wheels to their service. This invitation was responded to by some four or five representatives of the most prominent wheels. The tests showed the Pelton wheel to be 'nineteen per cent. in excess of the best showing made by any of the others. The test of the Pelton wheel there made proved the useful effect to be 87·3 per cent."

Prof. Irving P. Church (*Mechanics of Fluids.* New York: Wiley. 1889), in his discussion of the Pelton water wheel, gives the Pelton motor "a theoretical efficiency of unity, the water leaving the buckets without velocity. The wheel in practice utilises eighty to eighty-five per cent. of the issuing water."

Professor Dwight Porter, associate professor in the Department of Hy-

draulic Engineering of the Massachusetts Institute of Technology, communicates the following:

"The four-foot Pelton water wheel in our hydraulic laboratory has been used in regular class tests for one season only, with the following results: In twenty-two tests with a one and three-eighth inch nozzle tip in use, under heads ranging from fifty-four feet to 171 feet, the velocity of rotation in no case varying more than eight per cent. from the theoretical best velocity, the efficiency has ranged between 71·2 per cent. and 81·4 per cent. for the entire series."

[Extract from a paper entitled "Water Motors as Marine Dynamo Drivers," by Lieut. F. J. Haeseler, U. S. N., published in the U. S. Naval Institute. U. S. Naval Academy, May 11, 1895.]

THE WATER MOTOR.

"The water motor used in the above-described comparison is manufactured by the Pelton Water Wheel Company, of San Francisco and New York. I have tested other makes of water motors and read of still other tests, and it has been my experience, as well as that of others making comparative tests with these motors, that they are at least fifteen per cent. and in some cases thirty-five per cent. more efficient. The firm claims an efficiency of eighty-five per cent. when the wheels are set in accordance with their instructions, and I have found their claims not only true, but below what is really obtainable. During the past two months Ensign W. H. G. Bullard, U. S. N., and the writer tested one of the Pelton wheels bought out of stock two years ago and without any expectation at that time of its being tested for efficiency.

"Tabulated below are the results of our tests, showing an efficiency at the higher pressures in excess of that claimed by the firm.

"Tests Nos. 1, 2, 3, 10 and 11 were made with the motor running at incorrect number of revolutions in order to determine the efficiencies when governing, in case the pressure on the whole jet was reduced and the revolutions kept up. Test No. 13 was the last one made, and it was noticed that the brake was binding closely on one side, which may have occasioned the lower efficiency.

## TESTS OF PELTON WATER MOTOR No. 4.

MADE BY LIEUT. F. J. HAESELER, U. S. N., AND ENSIGN W. H. G. BULLARD, U. S. N., AT THE UNITED STATES NAVAL ACADEMY, MARCH, 1895.

| *No. Test.* | *Size Jet. Inch.* | *Running Pressure.* | *Revolutions.* | *Actual Water Used.* | *Actual H. P. Developed.* | *Theoretical H. P. Possible.* | *Per Cent. Efficiency.* |
|---|---|---|---|---|---|---|---|
| 1 . . | ⅝ | 90 | 775 | 14·05 | 4·101 | 5·496 | 74·6* |
| 2 . . | ⅝ | 105 | 910 | 15·14 | 5·025 | 6·910 | 72·7* |
| 3 . . | ⅝ | 100 | 850 | 14·78 | 4·694 | 6·422 | 73·1* |
| 4 . . | ⅝ | 100 | 775 | 14·78 | 5·349 | 6·422 | 83·3 |
| 5 . . | ⅝ | 103 | 780 | 15·00 | 5·363 | 6·715 | 82·9 |
| 6 . . | ⅝ | 125 | 880 | 23·05 | 10·73 | 12·52 | 85·69 |
| 7 . . | ¾ | 102 | 775 | 20·82 | 7·845 | 9·226 | 85·02 |
| 8 . . | ¾ | 100 | 775 | 20·61 | 7·756 | 8·957 | 86·59 |
| 9 . . | ¾ | 125 | 900 | 23·05 | 10·67 | 12·52 | 85·16 |
| 10 . . | ¾ | 73 | 775 | 17·61 | 4·457 | 5·587 | 79·79* |
| 11 . . | ¾ | 86 | 880 | 19·11 | 5·365 | 7·143 | 75·12* |
| 12 . . | ¾ | 100 | 780 | 20·61 | 7·717 | 8·957 | 86·13 |
| 13 . . | ¾ | 142 | 900 | 24·56 | 12·84 | 15·16 | 84·70 |

* Tests marked thus (*) were made to find the efficiency of the governor. The motor was running at incorrect number of revolutions at the time for the pressure at the jet. The water used is in cubic feet.

"A Prony brake was used, with a stream of cold water running over it all the time, and two pieces of soap bearing against the pulley, like the brushes of a dynamo, kept the brake equally lubricated, and the pull on the scale was very steady. The pull was measured by a spring balance, the brake arm being kept horizontal all the time, and the balance was compared with the standard after each test, and in several cases the standard itself was used. The standard balance was verified before and after the series of tests, and was found to be accurate. The amount of water used was *absolutely measured* by running it into the pool of the natatorium of the Naval Academy, where the level of its surface could be measured by means of a float and rod, that could be read with exactness to the one-sixty-fourth of an inch, which corresponded to just one cubic foot. In this manner, a number of tests were made, and the coefficient of ajutage found to be ninety-five per cent. with the five-eighth inch jet, and ninety-two per cent. with the three-quarter inch jet, which agrees very closely with what they should be when worked out theoretically. After the coefficients were determined and found to be practically constant, the five-eighth inch jet not varying one per cent. in a range of pressures from 20 to 100 pounds, and the three-quarter inch jet not varying at all in from fifteen to fifty pounds, the water motor was moved to the power-house close to the pump, so as to get rid of pipe friction, and to have the pressures more under control. The amount of water then used was determined by using the coefficients of ajutage found as already described. The efficiencies thus determined can, therefore, be taken, as being reliable, and agree with those in testimonials published by the Pelton firm."

The case is clear, in the light of all our searches, that the bucket of Pelton is absolutely new, correct in principle and commercially important.

No. 4724 Springfield Avenue, Philadelphia, June, 1895.

# ASPHALTS AND BITUMENS.

By Samuel P. Sadtler, Ph.D.,
Professor of Chemistry in the Institute.*

In taking this subject for a short review, let us inquire as to the meaning of these words and the use that has been made of them. Here at the outset we are met with a considerable divergence of view and latitude, not to say looseness, of application.

In "Mineral Resources of the United States for 1893," published by the United States Geological Survey at Washington, we find, on page 627, under the heading "Asphaltum," the following statement: "Under this generic name one finds included bituminous rock, sandstones and limestones impregnated with bitumen or asphaltum, free bitumens, either liquid, viscous or solid, containing little or no mineral matter, and, finally, mixtures in various proportions, more or less intimate, of bitumens with inorganic matter, or with both inorganic and organic matter." This certainly is a wide range of application for the term asphaltum. On the other hand, Léon Malo and other French writers have sought to narrow its application to one class of natural product, as will be seen from the following quotation:

"Asphalt is a natural product, a bituminous limestone in which carbonate of lime and pure mineral bitumen are most intimately combined by natural agency, the proportions varying from seven per cent. bitumen and ninety per cent. carbonate of lime to two per cent. bitumen and eighty per cent. carbonate of lime."†

Similarly, Capt. F. V. Greene, in a paper read before the American Institute of Mining Engineers, October, 1888,

* A lecture delivered before the Mineralogical Section of the Brooklyn Institute, December 18, 1894, and repeated at the Franklin Institute by request.

† "Twenty Years Practical Experience of Natural Asphalt." W. H. Delano. E. and F. Spon. 1893.

after taking exception to Léon Malo's restricted use of the word, gives a table of the various forms of bitumen in which he limits the application of the word asphalt to "bitumen mixed with earthy matter," excluding, however, bituminous sandstones and bituminous limestones.

To clear up this matter and define in sufficiently broad, but exact terms, the proper use of the word asphalt, we must first refer to the meaning of the other term which I have used in choosing a subject for this lecture, viz.: *bitumen.* The word bitumen in mineralogy is applied to hydrocarbon mixtures of mineral occurrence, whether solid, liquid or gaseous. With this understanding of the nature of bitumen, we can adopt the very concise classification of Prof. S. F. Peckham, who published, in 1885, the "Special Report on Petroleum" for the tenth census. It divides bitumens into:

*Solid:* Asphaltum (German, *Asphalt* or *Erdpech;* French, *Asphalte*). *Semi-fluid: Maltha* (French, *Gondron minéral;* Spanish, *Brea*). *Fluid:* Petroleum. *Volatile:* Naphtha (German, *Naphta*). *Gaseous:* Natural Gas—of burning springs.

According to this classification asphaltum is simply a solid bitumen. It may be almost pure, as the so-called "Glance-pitch," Gilsonite, or Grahamite, and find its chief application in asphalt varnish making; or, it may contain earthy matter, varying in amount from two or three per cent. to the ninety per cent. of the so-called asphalt rocks.

The same classification has been adopted by Major J. W. Howard, in his pamphlet, "Natural Asphaltum and its Compounds," and by his courtesy I am enabled to show you his "Table of the Occurrence of Important Natural Bitumens," the most complete enumeration that, so far as I know, has been made:

- **Important Natural Bitumens.**
  - Natural gas . . . . . Ohio, Pennsylvania, California, etc., in the United States, Russia, France, etc.
  - Natural naphtha . . Found in petroleum districts (of little value, superseded by artificial naphtha from crude petroleum).
  - Petroleum . . . . . Pennsylvania, Ohio, Wyoming, California, etc., in United States, Russia, etc. (Consult books on petroleum.)
  - Maltha . . . . . California, Wyoming, Alabama, Utah, Colorado, Kentucky, New Mexico, Ohio, Texas, Indian Territory, etc., Russia, France, Germany, etc.
  - Asphaltum
    - **Asphaltum Almost Pure.**
      - North America . . . . Utah, California, Texas, etc.
      - Central America . . . Cuba, Mexico, etc.
      - South America . . . . Trinidad, Venezuela, Peru, Colombia, etc.
      - Europe . . . . . Caucasia, Syran on the Volga, Germany, France, Italy, Austria, etc.
      - Asia . . . . . Hit on the Euphrates, Asia Minor, Palestine, etc.
      - Africa . . . . . Oran in Egypt, probably other places.
    - **Asphaltic Compounds.**
      - North America . . . . West Virginia, Kentucky, Texas, Wyoming, Utah, Colorado, California, Indian Territory, Montana, New Mexico.
      - Central America . . . Mexico, Cuba, etc.
      - South America . . . . Trinidad (largest supply, most used), Venezuela, Peru, Colombia, etc.
      - Europe . . . . . Germany, Switzerland, France, Italy, Sicily, Russia, Austria, Spain, etc.
      - Asia . . . . . Asia Minor, Palestine, Bagdad, and probably in China.
      - Africa . . . . . Egypt and probably elsewhere in Africa.

We may now take up for special description the two classes of bitumens: the Malthas (or semi-liquid bitumens) and the Asphalts (or solid bitumens).

One of the earliest known and most famous occurrences of maltha or mineral tar was that of Bechelbronn in Alsace, which was described and studied by Boussingault. It is described as a viscid, tarry liquid, of bituminous odor, and a specific gravity 0·966. It was from this maltha that Boussingault obtained the products to which he gave the

names "petrolene" and "asphaltene," and which have played such an important part in asphalt literature. Kayser, who re-investigated the Bechelbronn maltha in 1879, considers that it is a solution of a sulphated hydrocarbon (asphaltene) in a liquid sulphur-free hydrocarbon (petrolene), and that the latter is present in much the larger amount. In his ultimate analysis of the maltha, Kayser notes, however, over 0·3 per cent. of nitrogen as also present.* This deposit has long since been worked out.

In this country mineral tar or maltha is found in a large number of States, especially in the West. The most important occurrences are those of southern California, in the counties of Kern, Ventura and Santa Barbara. Crude maltha or mineral tar, as found in California, is often mistaken for a heavy petroleum, or rather a petroleum residuum, as its gravity, 12° to 17° Baumé, corresponds with that obtained in such residuums; but, as pointed out by Professor Peckham, it differs in important particulars. The maltha in its crude state contains from twelve to fifteen per cent. of water, which will not settle out, but must be removed by heating to from 212° to 300° F. The amount of water retained by crude petroleums, incapable of settling out, on the other hand, is slight, not over one to two per cent. The crude maltha usually contains air, carbon dioxide, or hydrogen sulphide, in varying proportions, mechanically mixed with the viscous mass, so that when the maltha is heated to not more than 100° F., it begins to froth rapidly, and will usually fill both still, condenser and receiver with an overflow of foam before any of the water has been removed.

These malthas, likewise, contain, in the natural state, volatile oils and basic hydrocarbons, both of which have to be removed in the refining process.

Similar to this occurrence of natural malthas, although distinct from them, in respect of the conditions required for its extraction and possibly also in chemical characters, is the so-called "liquid asphalt" obtained at Las Conchas mine, some thirteen miles east of the city of Santa Barbara, in Santa

**Untersuchungen über Natürliche Asphalte*, p. 20.

Barbara County, Cal. Here is found a bed of clean sea-sand, holding, like a sponge, the thick maltha, which oozes up from underlying beds of shale.

It is stated that a well sunk 400 feet in this lower stratum continues to ooze maltha at all points. The mine is right on the edge of the ocean, and the sands extend some miles back from the beach. Covering the sand deposit is a surface deposit of light earth and soil, upon which is ordinary vegetation. This soil is "hydraulicked" off by a twelve-inch stream of clear salt water, and the maltha-containing sand uncovered. The separation of the maltha from the sand is accomplished not by distillation, but by mechanical means, and with the aid of specially designed machinery, by the California Petroleum and Asphalt Company, which sells it under the name of "Alcatraz liquid asphalt."

Crude maltha, under the several names of "liquid asphalt" and "mineral tar," is found also in Utah, Kentucky, Tennessee and Texas, although in most cases no attempt has been made to utilize these products commercially.

Let us pass now to solid bitumens or asphalts in the proper sense of the word. The purest of the solid bitumens are known sometimes as "glance-pitch" or "gum asphaltum." Prominent among them is the gilsonite of Utah. This is found in the Uintah Indian reservation in Wasatch and Uintah Counties. The purity of the gilsonite (some ninety to ninety-eight per cent. soluble in carbon disulphide), is such that it finds large application in the manufacture of varnishes and insulating compounds. The present production is some 2,000 tons annually. Glance-pitch also occurs in Texas, in Cuba and Mexico.

We come then to the asphalts which contain inorganic matter in varying amount as a uniform constituent of the mineral as it occurs in nature.

The two most important occurrences of these asphalts are those of the island of Trinidad, known as the Trinidad Lake asphalt, and of the province of Bermudez, in Venezuela, on the mainland, nearly opposite the island of Trinidad, and known as the Bermudez Lake asphalt.

The so-called "Pitch Lake" of Trinidad occurs on the west coast of the island. It is situated about a mile and a half from the sea coast, at a height of 138 feet above sea level, and occupies the crater of an old mud volcano. It forms, therefore, a circular mass of asphalt of an area of a little more than 114 acres, and of uncertain depth. Rude borings have been made which indicate a depth of seventy-eight feet in the center and about eighteen feet at the sides. If these figures are correct, the lake should contain about 6,000,000 tons of asphalt. Too much confidence, however, cannot be placed upon these borings, as the asphalt near the center seems to be softer than that around the edges and seems to rise readily to replace the portions removed. Whether the lake or deposit of asphalt is still fed from underground sources, as has been suggested by some authors, is not definitely known. While the term lake is used, it must not be supposed that the surface resembles that of a liquid, even a viscid liquid. On the contrary, the surface shows a brownish, earthy material, with cracks or fissures here and there of a width and depth of several feet, some filled with rain-water, and some with earth, supporting a scrubby vegetation. Carts and mules, it is stated, can be driven everywhere on the surface. The material is dug with a pick and shovel, loaded into carts, and hauled to the beach to be loaded on lighters which carry it to the vessels. During the voyage to this country, the material unites into a solid mass, and must be removed from the hold by the use of the pick and shovel.

The crude Trinidad Lake asphalt has the following composition:

| | *Per Cent.* |
|---|---|
| Bitumen | 39·83 |
| Earthy matter | 33·99 |
| Vegetable matter | 9·31 |
| Water | 16·87 |
| | 100·00 |

After a refining process, in which it is heated in large tanks to a temperature of not much over 300° F., in order to drive off the water and allow portions of the earthy

matter to settle and of the vegetable matter to be skimmed off, it has the following composition:

| | *Per Cent.* |
|---|---|
| Bitumen (by $CS_2$) | 59·86 |
| Earthy matter | 35·82 |
| Vegetable matter | 4·32 |
| | 100·00 |

Besides this lake asphalt, the island of Trinidad also yields a "land asphalt," from the neighborhood of the lake.

This asphalt may have come from overflows of the main deposit in past ages, or it may have an independent, although analogous, origin. It seems harder and more earthy than the lake deposit, and its bitumen shows differences in solubility and other physical properties.

The exportations of the Trinidad Lake asphalt have increased rapidly in recent years, and amounted in 1892 to 96,319 tons, and in 1893 to 88,881 tons.

The Bermudez asphalt also comes from a so-called "pitch lake," situated in the State of Bermudez, in the republic of Venezuela. The deposit is some eighteen miles from the mouth of the San Juan River, which empties into the Gulf of Paria, opposite to, and about one hundred miles distant from, the island of Trinidad. A narrow-gauge railroad runs from the shipping point, Guanoco, on the San Juan River, to the lake, a distance of six miles. The deposit, or lake, covers an area of over 1,000 acres, and is of unknown depth. While vegetation is found growing in irregular patches over the surface, it is only superficial, and a uniform deposit of asphalt is found underneath.

The Bermudez asphalt, as dug from the lake, is a solid bitumen of great purity, containing, according to an analysis recently made, but 2·63 per cent. of mineral matter and about 1·3 per cent. of organic non-bitumen, with several per cent. of water, leaving over 90 per cent. of bitumen soluble in carbon disulphide.

The refined asphalt, obtained by a process similar to that spoken of under Trinidad asphalt, is slightly purer, being:

| | *Per Cent.* |
|---|---|
| Bitumen (by $CS_2$) | 97·22 |
| Mineral matter | 1·50 |
| Organic non-bitumen | 1·28 |
| | 100·00 |

This asphalt is, of course, notably softer and more plastic than the Trinidad Lake asphalt, which in its refined state carries some 35 per cent. of mineral matter (chiefly clay and oxide of iron) as compared with 1·50 per cent. of the Bermudez.

The natural asphalts (or solid bitumens) of California are also very important and of a high degree of purity. Thus, the La Patera mine, situated twelve miles west of Santa Barbara, and at a depth of 125 feet, yields a compact solid rock of the composition:

| | *Per Cent.* |
|---|---|
| Bitumen soluble in $CS_2$ | 59·15 |
| Mineral matter | 39·75 |
| Organic non-bitumen | 1·10 |
| | 100 00 |

The deposit covers several hundred acres, and is mined much in the same manner as coal. It is not soft, but is friable, and breaks readily under the pick or wedge. The mineral residue is fine silica, free from clay and organic matter.

Similarly in Kern County, California, are extensive deposits of a solid asphaltum worked by the Standard Asphalt Company. This material in its crude state shows the following composition:

| | *Per Cent.* |
|---|---|
| Bitumen soluble in $CS_2$ | 84·79 |
| Mineral matter | 8·70 |
| Organic non-bitumen | traces |
| Moisture | 6·51 |
| | 100·00 |

An interesting feature in connection with this asphalt is that the mineral matter consists almost entirely of infusorial earth, or silica of organic origin, possessing a peculiar absorbent character.

Other asphalts of this class, that is, solid mixtures of bitumen and earthy material, are those of Cuba containing some seventy per cent. of bitumen, and of Syria containing from seventy-five to ninety per cent. of bitumen.

We have now to consider the case of bituminous or bitumen-saturated rocks. These are included in two classes: Bituminous limestones and bituminous sandstones. The former class includes the best known and most generally used asphalts of Europe. We have among these the mines at Seyssel-Pyrimont in the Department of Ain, France; those of Val de Travers in the Canton of Neufchatel, Switzerland; those of Ragusa in the island of Sicily; of Limmer, near Hanover, Germany; and of Vorwohle, in Germany. These asphalts are in general composed of a fine amorphous limestone, saturated with from five to fourteen per cent. of bitumen. The subjoined analyses, taken in part from Howard's pamphlet and in part from the "Mineral Resources of the United States for 1893," will show the composition of these asphalts:

| | Seyssel, France. | Val de Travers, Switzerland. | Ragusa, Sicily. | Limmer, Germany. | Vorwohle, Germany. |
|---|---|---|---|---|---|
| Bitumen | 8·15 | 10·15 | 8·92 | 14·30 | 5·37 |
| Calcium carbonate | 91·30 | 88·40 | 88·21 | 67·00 | 90·80 |
| Magnesium carbonate | ·10 | ·30 | ·96 | — | — |
| Clay and oxide of iron | ·15 | ·25 | ·91 | 17·52 | ·59 |
| Sand | — | — | ·60 | — | 2·55 |
| Insoluble | ·10 | ·45 | — | — | — |
| Loss | ·20 | ·45 | ·40 | 1·18 | ·34 |
| | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 |

One very characteristic occurrence of bituminous limestone is found in the United States, viz.: the so-called litho-carbon in Uvalde County, Texas. The mineral here found, according to "Mineral Resources of the United States for 1893," is a bituminous limestone, the limestone being a shell deposit, in which the original forms are still maintained. The rock contains from fifteen to thirty-three per cent. of bitumen, the average being about twenty per cent. The refined product is said to possess peculiar

properties, being especially noted for its elasticity, making it, in this respect, somewhat similar in character to elaterite.

In this country the bituminous sandstones occur chiefly in California, Utah and Kentucky. In the State first named these sandstones are found at various points between San Francisco and Los Angeles, in the counties of Santa Cruz, San Luis Obispo, Santa Barbara, and Ventura. They contain from twelve to eighteen per cent. of bitumen and are easily pulverized when heated. They are used in most cases without other admixture for street paving, being rolled or tamped thoroughly while hot. Similar products are obtained from Utah and Kentucky, although that from Utah is often too rich in bitumen to be used for paving purposes without farther dilution with sand.

The production of asphaltum and bituminous rock in the United States for 1893 is given by the United States Geological Survey in "Mineral Resources of the United States for 1893," as 47,779 tons, of which California produced 42,650 tons, Utah 3,200 tons, and Kentucky 1,929 tons. For 1892 the production is given as 87,680 tons.

If we turn now to the question of the nature of the bitumen in these natural asphalts and malthas, we will find much to interest as well as to perplex us. Mention was made, in speaking of Boussingault's studies of the Bechelbronn mineral tar, of the distinction made by him of "petrolene" and "asphaltene," and of the definitions given those terms later by Kayser. We know now that there are no well-characterized compounds to which these names can be given but that the materials (obtained by fractional solution with different solvents) to which these names have been given are mixtures. In general, the mixture called "petrolene," and which is extracted from these natural asphalts by means of petroleum ether, acetone or common ethylic ether, is tough, viscid, and of great cementing quality, although soft; while that called "asphaltene," and which is extracted from the residue with hot turpentine, chloroform or carbon disulphide, is dry, friable and brittle; but the proportions of these extracted from one and the same asphalt, as has recently been very

clearly shown by Miss Laura A. Linton,* in an article on the "Technical Analysis of Asphaltum," will vary quite notably according to the choice of the solvent. It is, therefore, very obvious that the analyses before quoted of individual asphalts are, strictly speaking, not comparable, unless we know something as to the nature of the bitumen, of which the percentage is stated in a general way only. This may be illustrated by two analyses, for which I am indebted to a private communication of Dr. F. Salathé, chemist of the Standard Asphalt Company, of California. The first is of the crude black asphalt from Kern County, Cal., and which has been already mentioned; the second is of a light brown, friable, and non-cohesive rock, found near the surface of the asphalt vein:

| | Total Bitumen. | Per Cent. of Total Bitumen Soluble in Acetone. | Per Cent. of Total Bitumen Left, Soluble in Chloroform. |
|---|---|---|---|
| Crude black asphalt . . . . . | 84·79 | 67·50 | 32·50 |
| Crude brown asphalt . . . . . | 82·08 | 21·30 | 78·70 |

Two analyses from Miss Linton's article may be quoted also, as showing this difference in the nature of the total bitumen:

| | Petrolene. | Asphaltene. | Non-bituminous Organic. | Mineral Matter. | Water. |
|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| Crude Trinidad asphalt . . . . . | 32·445 | 22·112 | 8·121 | 35·286 | 2·039 |
| Crude Cuban asphalt . . . . . | 25·460 | 54·414 | 2·469 | 17·030 | 0·391 |

Again, if we turn to the ultimate analyses of the bitumen contained in the asphalts, we have many points of interest. The Trinidad and Bermudez, as well as the Syrian asphalts, contain notable quantities of sulphur more or less firmly combined with the hydrocarbons, while the California malthas and asphalts are nearly free from sulphur, but always contain nitrogen. Moreover, as was first observed by Dr. Salathé and confirmed by Prof. S. F. Peckham, this

**Journal of the American Chem. Soc.*, Dec., 1894, p. 817.

nitrogen is due to the presence of pyridine and quinoline bases, compounds which apparently indicate an animal origin for these bitumens. By studying the crude petroleums of California, Professor Peckham has found that the basic oils in their natural condition were combined with an exceedingly viscous, feebly acid, tar. Upon these observations he has founded an extremely interesting theory respecting the gradual changes whereby the California asphalts at least have been produced, and which I will give in his own words:*

"A number of facts observed indicate that all those forms of bitumen that have been least exposed to the action of atmospheric oxygen contain the largest proportion of basic oils. Analysis shows less nitrogen in the malthas, and still less in the asphaltums, than in the petroleums. It appears that the compound ethers or *esters* which exist in the native petroleums are decomposed with substitution of oxygen for nitrogen. This substitution I have made artificially. The result is the precipitation of the acid radical as a hydrate within the oil, in which it dissolves, producing a viscous tar. When this decomposition has proceeded so far that water in appreciable quantity becomes a constituent of the compound, the bitumen is no longer petroleum, but maltha. This water of hydration separates only when the maltha is heated to a comparatively high temperature. It will never separate by difference of specific gravity at comparatively low temperatures, but requires a temperature at which the hydrate is decomposed into a dense oil very much less viscous than the hydrate on the one hand and water on the other.

"As the change proceeds, the bitumen becomes solid asphaltum, and a new compound, that is found in maltha only in small quantity, if at all, appears. This is Boussingault's *asphaltene*, which was assumed by him to be an oxidized product in which oxygen was substituted for hydrogen. Recent experiments, not yet completed, indicate that asphaltene is not a simple substance, but that it may be resolved by suitable solvents into a compound containing oxygen and a compound that represents the original hydrocarbon, minus a portion of its hydrogen, by virtue of which it is no longer soluble in those fluids that dissolve the hydrocarbon in its original form."

There remains the practical side of the subject to be noted.

The uses of asphalt may be summarized as follows:

(1) As a varnish or paint.
(2) As the base of insulating compositions.
(3) As a waterproofing material.
(4) As a cement in ordinary building construction.
(5) As the cement in roofing and paving compositions.

*Amer. Jour. of Science*, Sept. 1894, p. 254.

(It is stated that fully ninety-five per cent. of the asphalt used is for the last-named purpose.)

For the manufacture of asphalt varnish or paint, the asphalts rich in bitumen (like gilsonite) are used, the bitumen being partly dissolved by admixture with oil of turpentine and linseed oil. In this way a so-called Japan varnish is obtained for the process of japanning metals. The asphalt varnish may also have other resins (like shellac) added in order to give greater flexibility and toughness.

For the manufacture of insulating compounds the asphalt is usually tempered with wax tailings and other petroleum products to give the mixture the proper consistency; the exact composition of the mixtures being, however, carefully kept secret by the manufacturers.

For waterproofing the foundations of buildings, and as a protection against moisture in cellars, etc., a refined maltha or melted asphaltum is often used, being painted on the masonry or timber, or bricks are dipped in it before being set in position. For lining reservoirs, irrigating canals and ditches, an asphalt cement similar to that used for paving is frequently used. In this case, as has been shown in practice, a natural asphalt with a proper proportion of bitumen and mineral matter, or a natural asphalt tempered with a maltha or so-called "liquid asphalt," will yield a more homogeneous and water-resisting coating material than an asphalt tempered with either coal tar or petroleum residuums.

For other forms of construction, especially for paving sidewalks, stable-yards, open areas and flooring in exposed positions, as upon flat enclosed roofs of large buildings, asphalt mastic is used. The basis of this is usually one of the natural asphaltic limestones, such as Seyssel or Neufchatel asphalt.

The rock, having been powdered, is put in round kettles in which about eight per cent. of its weight of refined Trinidad asphalt has been previously melted. It is thoroughly mixed with this at about 280° F. for several hours, and is then run into moulds, where it is formed into square,

hexagonal or round blocks, of about fifty to sixty pounds weight. When the mastic is to be used, it is again melted with refined Trinidad asphalt, in the proportions of about seven pounds of asphalt to 100 pounds of the mastic, and sand or fine gravel is added gradually up to sixty pounds, according to the use to which the mixture is to be put. This mixture, known as "gritted mastic," is spread while hot, rubbed smooth and allowed to cool. When cold it is slightly pliable and thoroughly waterproof.

The last-named application of asphalt, viz.: for roofing and paving construction, as before stated, is by far the most important of all the others. As applied to roadway or street-paving, we have two entirely distinct methods to note. The asphaltic limestones such as are found in Europe, and asphaltic sandstone such as is found in California, require merely to be crushed, heated to from 275° F. to 300° F., and hauled to the streets and spread uniformly while still hot. It is then tamped and rolled with hot instruments. Asphalt pavements of this kind are in general use in Paris, London, Berlin and other European cities. Roadways made from bituminous limestone are said to become polished by wear and to become slippery in foggy and drizzling weather. In California, where bituminous sandstone is used, they are said to wear well, except that they soften rather too much in warm weather.

The other form of asphalt paving construction, used most largely in this country, is that in which an asphalt cement is first made by taking a hard but relatively pure asphalt and tempering it with some oily or bituminous liquid. This cement, in the proportion of ten to sixteen parts, is then mixed at a temperature of about 300° F. with from eighty-four to ninety parts of clean sand and powdered limestone, and the mixture applied with no more loss of heat than necessarily follows its transportation to the streets in covered carts.

While this general statement as to the nature of an asphalt paving composition may be taken as covering the subject broadly, many points of the greatest importance come in to determine whether a given composition will be

a satisfactory one or otherwise. The asphalt should be one with a high percentage of so-called petrolene as compared with asphaltene; the oily or bituminous liquid above referred to should be one that will make a satisfactory and durable blending with the asphalt, and the proportions of tempering liquid and asphalt which go to make up the cement should be chosen with reference to climate and the character of the traffic that is likely to pass over the street.

The analyses quoted in this lecture will show how asphalts may differ in the first respect. With regard to the nature of the tempering liquid, I may say that coal tar was at one time used, but has been almost universally rejected, as not making a satisfactory or durable blending material, the mixture having been found to disintegrate under atmospheric influences. Petroleum residuums are now almost universally used in the Eastern States, while malthas, or natural "liquid asphalts," so-called, are used on the Pacific Coast and in Western States. I am satisfied, on both theoretical and experimental grounds,* that the last-named tempering materials are to be preferred. The time allowed for an illustrated lecture on a broad, general subject of the nature of this will not allow me to go into a discussion of this question here. Thanking my audience for their kind attention, I will therefore bring my account of asphalts to an end.

## RAINFALL AND TYPHOID FEVER.

By Wm. P. Mason.

The first, or at least one of the first, to call attention to the relation between water and typhoid fever was Dr. Michel, of Chaumont, France. In 1855 he observed that typhoid, which was epidemic in the above place, varied in number of cases and in intensity inversely as the quantity of water in the public wells.

Pettenkoffer, of Munich, about the same time, undertook extended observations upon variations in the height of

* *Paving and Municipal Engineering*, September, 1894, p. 118.

ground water, and, a little later, relationship was shown between these variations and the occurrence of typhoid fever.

Those who hold with Pettenkoffer, claim that the elements of the disease readily multiply in the soil, and are driven therefrom along with the ground air, upon the rising of the water level at the time of the autumnal rains.

Latham, in speaking upon this point, says:

"No great variation in the vertical rise and fall of subsoil water is the healthier condition. The ground always contains air, and, as the ground water sinks, air is drawn in to supply its place. After long dry weather, the air of the soil is thus laden with products of decomposition. A rain now occurring, the ground air is displaced, and since said rain is liable to seal the surface, the tendency of the air is to escape laterally, *i. e.*, into cellars. Dry summers invariably mark unhealthy years. Typhoid fever occurs after the autumn rains.

"All the great epidemics of typhoid have occurred in years when the ground water was especially low, and after a slight rise in the same."

Pettenkoffer's "ground-air theory" is not gaining the majority of supporters, a more reasonable view being, that as the water surface lowers in a well, the base of the cone of drainage, whose apex is at that surface, is extended, and consequently, more widely situated points of pollution are embraced within its influence.

Perhaps the most exhaustive examination of the relation of the height of ground water to the prevalence of typhoid that has been made in America, is to be found in the work of the State Board of Health of Michigan.

Observations have been made by that Board during a period of many years, and the results, graphically shown herewith, indicate in a very marked manner that increase of typhoid and lowness of water in wells move in practically the same curve of variation.

So convinced were the Michigan authorities of the truth of this proposition, that they issued, during the past autumn, a circular of warning, which is here quoted in part:

"*Beware! Unusual Danger now from Typhoid Fever, because of Drought.*

"The water in the representative well near the center of the State, last September, was three inches more than the average of previous years; this year it is four inches less than the average.

"For the second week in September, typhoid fever is reported from thirteen places more this year than last year, etc., etc."

The Michigan statistics go, further on, to show that in October, 1894, the water in the standard well stood eleven inches lower than in October, 1893, and seven inches lower than the October average for the eight years, 1886–1893.

For September, 1894, typhoid fever was reported from 121 places in the State, an increase of forty-six places over the report for September, 1893.

For October, 1894, typhoid was present at 165 places, as against 109 for the same month of 1893.

For October, 1894, the prevalence of the disease is forty-four per cent. above the October average for the eight years, 1886–1893.

During the three months of September, October and November, 1894, the ground water of Michigan grew constantly lower. It is difficult to see just how these data could be made to fit the "ground-air" theory of Pettenkoffer or Latham as a cause of typhoid fever; for such theory calls for sudden rise in ground-water level.

The precipitation data for Michigan are:

| | *1893.* | *1894* | *Normal.* |
|---|---|---|---|
| January | 2·55 | 1·88 | 2·18 |
| February | 2·65 | 1·81 | 2·67 |
| March | 2·39 | 2·16 | 2·32 |
| April | 4·43 | 2·28 | 2·44 |
| May | 2·79 | 5·79 | 3·52 |
| June | 3·26 | 2·82 | 3·91 |
| July | 2·74 | 1·40 | 3·09 |
| August | 1·19 | 0·49 | 3·04 |
| September | 2·34 | 3·42 | 3·00 |
| October | 3·67 | 2·86 | 3·05 |
| November | 2·90 | 1·76 | 3·02 |
| December | 3·64 | 1·33 | 2·51 |

It has been the continued experience in Michigan that typhoid is coincident with low ground water, as is illustrated graphically herewith, and is not dependent upon sudden rise in the same. An interesting exception to this rule has been noted, occurring during the season of heavy frost, when surface pollution is prevented from reaching the subsoil.

Dr. Henry B. Baker, Secretary of the Michigan State Board of Health, to whom I am indebted for much information, also furnished me with this table:

EXHIBITING THE AVERAGE TOTAL ANNUAL RAINFALL AT STATIONS IN MICHIGAN THE SAME FOR LANSING, THE INCHES OF EARTH ABOVE THE GROUND WATER AT LANSING, THE INCHES OF WATER IN AN UNDISTURBED WELL AT LANSING, AND THE REPORTED SICKNESS, FROM TYPHOID FEVER IN MICHIGAN, AS INDICATED BY THE PER CENT. OF ALL THE WEEKLY CARD-REPORTS WHICH STATED THE PRESENCE OF TYPHOID FEVER DURING THE SEVEN YEARS AND EACH OF THE SEVEN YEARS, 1885-91:

| Year, and Period of Years. | Average Total Annual Rainfall at Stations in Michigan, in Inches. | Total Annual Rainfall at Lansing, in Inches. | Inches of Earth above the Ground Water at Lansing. | Inches of Water in an Unused Well at Lansing. | Ground Water Higher (+) or Lower (−) than the Seven Years' Average in Inches. | Average Per Cent. of all Weekly Card-Reports during the Presence of Typhoid Fever. | More (+) or Less (−) Sickness from Typhoid Fever than the Seven Years' Average. |
|---|---|---|---|---|---|---|---|
| Av. 7 years, 1885-91 . . | 31·06 | 29·45 | 293 | 31 | = | 9 | = |
| 1885 . . . . . | 35·82 | 34·51 | 284 | 40 | + 9 | 8 | − 1 |
| 1886 . . . . . | 32·76 | 29·52 | 281 | 42 | + 11 | 8 | − 1 |
| 1887 . . . . . | 29·82 | 30·08 | 290 | 34 | + 3 | 10 | + 1 |
| 1888 . . . . . | 29·55 | 25·76 | 294 | 29 | − 2 | 10 | + 1 |
| 1889 . . . . . | 28·18 | 23·28 | 304 | 19 | − 12 | 10 | + 1 |
| 1890 . . . . . | 30·20 | 33·96 | 300 | 28 | − 3 | 8 | − 1 |
| 1891 . . . . . | 31·66 | 29·05 | 301 | 23 | − 8 | 11 | + 2 |

We do not possess in New York so complete records as to the condition of the ground water as they have in Michigan; but the rainfall, upon which ground water depends, is on record, and the reports show that more than the average amount of rain fell in New York during the autumn past, following, as it did, an exceedingly dry summer.

If typhoid fever bears relation to sudden rise in level of ground water, as has been held, rather than to the prolonged low state of such level, as is taught in Michigan, then surely the autumn of 1894 was a favorable time for a marked outbreak of the disease in the State of New York, but no such condition is reported by the sanitary authorities.

Just how the year of 1894 compared, in the matters of typhoid and rainfall, with 1893 and 1891, may be seen from the accompanying charts.

The above years were chosen for comparison because the summer of 1893 was very wet, and because the entire year of 1891 was especially noted for prevalence of typhoid fever.

These curves are very irregular, and suggest in places relation between low rainfall and prevalence of the disease; but the remarkable concordance exhibited in the Michigan chart is here sought in vain.

New York does not stand alone in its failure to accord with the Michigan rule, as is seen from the following Connecticut statistics:

| | 1894. | | 1893. | | Normal. | |
|---|---|---|---|---|---|---|
| | Rainfall in Inches. | Deaths Typhoid. | Rainfall in Inches. | Deaths Typhoid. | Rainfall in Inches. | Deaths Typhoid. |
| July | 2·40 | 15 | 1·89 | 18 | 4·99 | 14·8 |
| August | 1·70 | 38 | 4·86 | 14 | 5·17 | 32·8 |
| September | 4·63 | 38 | 2·24 | 37 | 3·76 | 41·4 |
| October | 6·11 | 32 | 4·73 | 49 | 3·90 | 42·6 |
| November | 4·23 | 37 | 2·56 | 35 | 3·90 | 40·2 |

As elsewhere, so in Connecticut, the summer of 1894 was very dry, and very heavy rains fell in the autumn, yet the autumn death rate was below the normal. If any weight is to be attached to the *sudden rise* in ground water, surely here was an opportunity for its exhibition; but the rise in water level was followed by no increase in typhoid.

Minnesota was also an apparent exception to the Michigan rule, as we see from the following:

| | 1894. | | Normal. | |
|---|---|---|---|---|
| | Rainfall in Inches. | Deaths Typhoid. | Rainfall in Inches. | Deaths Typhoid. |
| August | 1·22 | 39 | 2·80 | 43 |
| September | 2·04 | 42 | 2·04 | 67 |
| October | 3·37 | 47 | 1·55 | 87 |
| November | 0·54 | 30 | 0·69 | 62 |

This State presents a refutation of the "ground air" theory, for there was certainly a "sudden rise" in level of the ground water, without corresponding increase of typhoid; but there is no real exception here to the "Michigan rule," for it will be remembered that the said rule calls for marked lowness of ground water, and we notice that the autumn rainfall was above the normal in this State.

Among the other States heard from, the majority unquestionably fall under the Michigan rule. Definite information regarding mortuary statistics, was, in the cases of many States, impossible to secure, and only such expressions as "considerable typhoid," "largely increased typhoid" were obtainable. No statistics whatever are kept in certain States, and from them no results could be recorded.

The health department of Iowa writes, under date of December 17, 1894:

"There is greatly increased typhoid fever in this State. Scarcely a town or township is exempt."

The Iowa rainfall was:

| | *1894.* | *Normal.* |
|---|---|---|
| August | 1·58 | 3·60 |
| September | 3·57 | 3·70 |
| October | 2·67 | 2·85 |

Here again is noticed the probable low condition of ground water, and the application of the Michigan rule.

The Board of Health of Ohio writes: "We have noticed a very decided increase of typhoid fever in our State during the past autumn. It has also been noticeable that the increase has been almost wholly in our small villages, where wells are used for water supply."

The Ohio rainfall was:

| | *1894.* | *Normal.* |
|---|---|---|
| August | 1·67 | 3·04 |
| September | 3·31 | 2·94 |
| October | 2·01 | 2·57 |
| November | 2·17 | 2·99 |

This was also an instance of prolonged low water, with results following the rule.

In Pennsylvania, the records show large amount of typhoid present during the past autumn, with rainfall as follows:

| | *1894.* | *Normal.* |
|---|---|---|
| August | 1·84 | 4·90 |
| September | 6·30 | 3·72 |
| October | 4·26 | 3·48 |
| November | 2·50 | 3·33 |

A word is necessary here regarding the great precipitation for September. It will be remembered that, on the eighth of that month, an exceedingly violent storm swept over the eastern coast of the United States, with very heavy rainfall.

A great portion of this rain found its way directly to the streams and water-ways, and the ground water received but little reinforcement.

In Maryland "there has been a decided increase in the number of typhoid fever cases during the past six months (*i. e.* June to December) in all parts of the State. The rate of mortality has been low."

The rainfall was:

| | *1894.* | *Normal.* |
|---|---|---|
| August | 1·55 | 4·76 |
| September | 2·45 | 3·87 |
| October | 3·17 | 3·76 |
| November | 3·65 | 2·78 |

Low condition of ground water is here very apparent, and the State falls under the rule.

In Wisconsin "there is thought to have been a slight increase of typhoid in the State during the past autumn but not very marked."

The Wisconsin rainfall was:

| | 1894. | 1893. |
|---|---|---|
| August | 0·78 | 2·03 |
| September | 3·58 | 2·32 |
| October | 3·04 | 2·49 |
| November | 1·93 | 1·33 |

Comparison with the normal for this State is not possible from the data in my possession. It will be noticed, however, that the autumn was probably wet, and the typhoid was practically normal.

I do not possess the normal values for Massachusetts, but a comparison of 1894 with the previous year stands as follows:

| | 1894. | | 1893. | |
|---|---|---|---|---|
| | *Typhoid.* | *Rain.* | *Typhoid.* | *Rain.* |
| August | 27 | 1·75 | 40 | 5·22 |
| September | 83 | 3·46 | 60 | 2·38 |
| October | 60 | 4·96 | 116 | 4·01 |
| November | 58 | 3·36 | 104 | 2·17 |

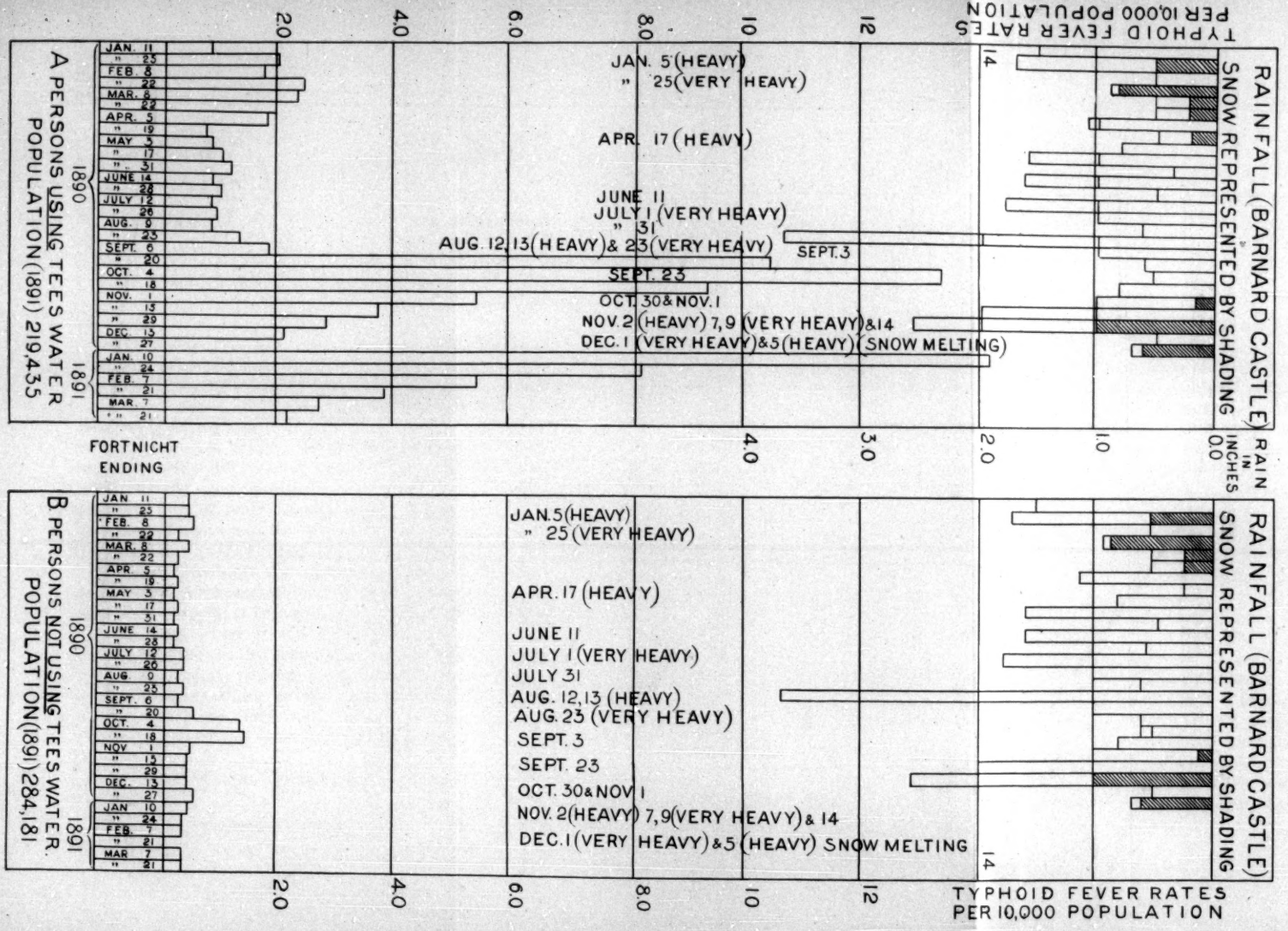
Evidently, Massachusetts is not to be rated as in accord with the Michigan rule.

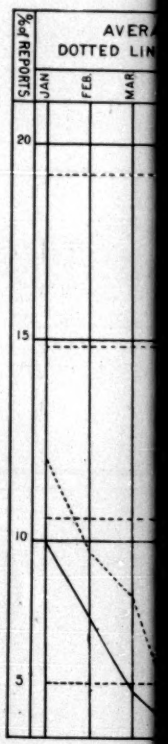
In Indiana, so far as the Board of Health has been advised, "there has been about the usual amount of typhoid fever, following dry weather, more than there is after a season of plentiful rainfall."

The Western States, so far as heard from, are thus seen to follow, as a class, what has been styled the "Michigan rule," with the apparent exception of Minnesota; but it has been shown that this is really no exception at all in view of the more than normal rainfall. Now, what reasonable explanation can be given for the failure of New York, Connecticut and Massachusetts to accord with the rule?

While not wishing to dogmatize upon manifestly scanty data, the suggestion is offered that, so far as these three States are concerned, larger shares of their populations derive their drinking water from more or less carefully selected sources of public supply, and are consequently less exposed to danger from the local contamination of private wells.

Whether the exhaustive study of facts does, or does not,


TYPHOID FEVER RATES PER 10,000 POPULATION
2.0
4.0
6.0
8.0
10
12
14
RAINFALL (BARNARD CASTLE)
SNOW REPRESENTED BY SHADING
RAIN IN INCHES
0.0
1.0
2.0
3.0
4.0
A PERSONS USING TEES WATER
POPULATION (1891) 219,435
1890
1891
JAN. 11
" 25
FEB. 8
" 22
MAR. 8
" 22
APR. 5
" 19
MAY 3
" 17
" 31
JUNE 14
" 28
JULY 12
" 26
AUG. 9
" 23
SEPT. 6
" 20
OCT. 4
" 18
NOV. 1
" 15
" 29
DEC. 13
" 27
JAN. 10
" 24
FEB. 7
" 21
MAR. 7
" 21
FORTNIGHT ENDING
JAN. 5 (HEAVY)
" 25 (VERY HEAVY)
APR. 17 (HEAVY)
JUNE 11
JULY 1 (VERY HEAVY)
" 31
AUG. 12, 13 (HEAVY) & 23 (VERY HEAVY)
SEPT. 3
SEPT. 23
OCT. 30 & NOV. 1
NOV. 2 (HEAVY) 7, 9 (VERY HEAVY) & 14
DEC. 1 (VERY HEAVY) & 5 (HEAVY) (SNOW MELTING)
B PERSONS NOT USING TEES WATER.
POPULATION (1891) 284,181
JAN. 5 (HEAVY)
" 25 (VERY HEAVY)
APR. 17 (HEAVY)
JUNE 11
JULY 1 (VERY HEAVY)
JULY 31
AUG. 12, 13 (HEAVY)
AUG. 23 (VERY HEAVY)
SEPT. 3
SEPT. 23
OCT. 30 & NOV 1
NOV. 2 (HEAVY) 7, 9 (VERY HEAVY) & 14
DEC. 1 (VERY HEAVY) & 5 (HEAVY) SNOW MELTING
TYPHOID FEVER RATES PER 10,000 POPULATION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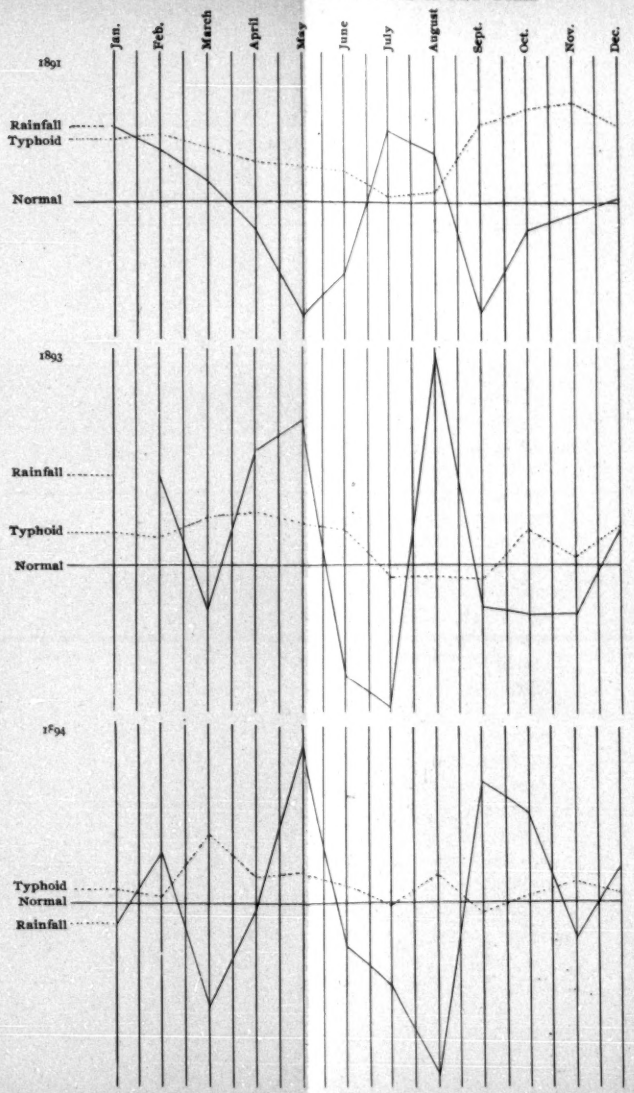
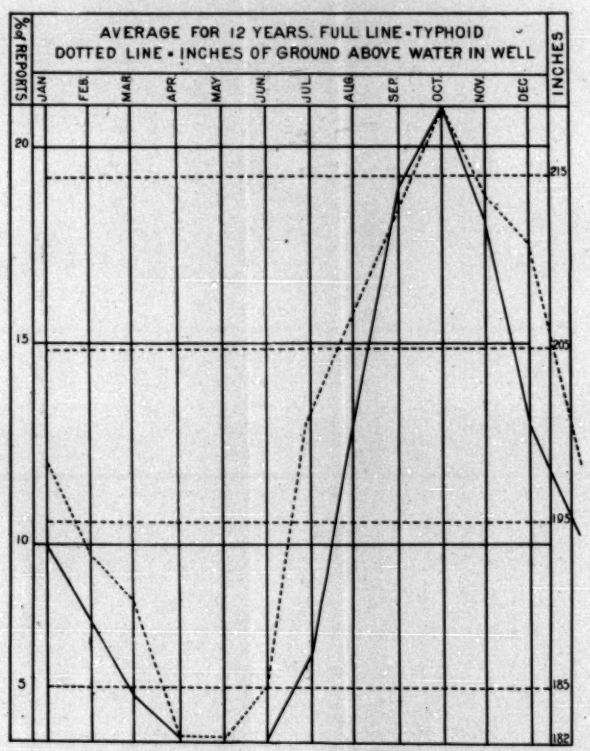
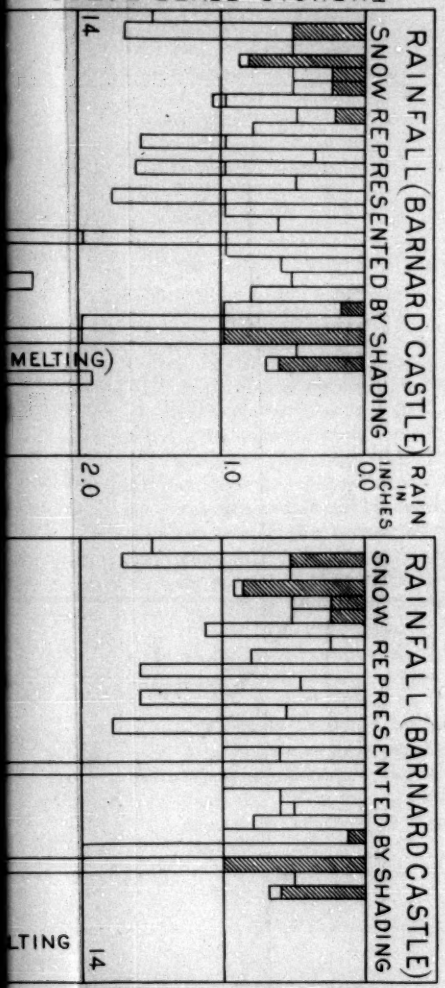
VARIATIONS FROM NORMAL—STATE OF NEW YORK.




LOW WATER IN WELLS AND TYPHOID FEVER—MICHIGAN.



support the view that the relation of typhoid fever and rainfall, so far as ground water is concerned, deals with the question of low ground water, rather than with fluctuations in its vertical height, it admits of ready illustration that marked relationship certainly exists between this disease and the sudden influx of storm waters, which flood the polluted channels of some smaller rivers.

A recent publication of the London Local Government Board deals with this question most thoroughly, in an inquiry concerning a typhoid fever outbreak occurring in the valley of the river Tees.

The Tees is a small stream of northern England, about seventy miles long, and navigable for about four miles from its mouth.

Many important towns upon its banks pump from this river, and a goodly number of the inhabitants of the sanitary district use its waters for domestic purposes.

In many places, especially in the towns, it receives all sorts of polluting additions, which are carried on by the current to intakes below. During dry weather, the stream recedes considerably, leaving uncovered its rocky foreshores (shown in the accompanying views), which receive and accumulate filth of every variety, and retain the same until, by reason of heavy rain, the river suddenly rises and sweeps the refuse downward towards the towns nearer the sea.

The result produced upon the thoughtless public, of such an extra and concentrated dose of sewage material added to their water supply, is best shown graphically by the accompanying chart, where it will be observed that increase of rainfall is followed by increase in cases of typhoid fever, among the 219,435 persons using the Tees water, after an interval corresponding to the incubation period of the disease, while no appreciable result is noticed among 284,181 people of the same district, using other sources of supply.

The "typhoid rates" given in the chart are "cases," not "deaths."

Rensselaer Polytechnic Institute, Troy, N. Y., April, 1895.

# CHEMICAL SECTION.

*Stated Meeting of June 18, 1895.*

MR. J. H. EASTWICK in the Chair.

## INVESTIGATION OF UTAH GILSONITE, A VARIETY OF ASPHALT.

BY WM. C. DAY.

A study of the literature of asphalt and allied bitumens reveals but few publications which throw light upon the true nature of these bodies, or of the classes of hydrocarbons which, in intimate mixture, appear to constitute them.

Boussingault* studied the bitumen of Bechelbronn with reference to the action of solvents upon it, and also the products resulting from distillation under the ordinary atmospheric pressure. By heating the material in an oil bath to the temperature 230° C. for a long time (*i. e.*, a number of days), he obtained a distillate to which he gave the name "petrolene," while the undistilled residue he called "asphaltene." The distilled "petrolene" showed a brown color, which was regarded as due to asphaltene mechanically carried over. After drying over calcium chloride, the petrolene was rectified and described then as being in a state of purity, having a pale yellow color, and an odor like bitumen. Its density was given as 0·891 at 21° C., and its boiling point 280° C. It was slightly soluble in alcohol, and much more so in ether. In a note he says that it is impossible to determine the proportions of asphaltene and petrolene by the heating method, since the petrolene oxidizes and becomes converted into asphaltene. On the basis of combustions of asphalt purified by ether, he gives the proportions of asphaltene and petrolene as 85·4 per cent. and 14·6 per cent., respectively.

**Ann. d. Ch. et de Phys.*, II, **64**, 141.

An elementary analysis of the asphalt gave the following figures:

| | *Per Cent.* |
|---|---|
| C. | 85·90 |
| H. | 11·25 |
| O. | 2·85 |
| | 100·00 |

It is noteworthy that in this analysis no mention is made of nitrogen or sulphur.

Völckel* investigated the mineral tar from Dax. Of this he found 50 per cent. soluble in ether. The ethereal solution becomes turbid upon the addition of absolute alcohol, precipitating a blackish-brown mass. Using a large excess of alcohol, only a small amount of oil remains undissolved in the mixture of alcohol and ether. The material left behind on evaporating the ethereal solution he regards as identical with the asphaltene of Boussingault.

By distilling asphalt rock in iron cylinders a peculiar volatile oil is obtained, having an odor like mineral tar, and a faint taste. It is insoluble in water and alcohol, but readily soluble in ether. The distillate, when distilled by itself, or with water, always shows a yellowish color. This yellow color is ascribed to a small amount of yellow oil, which, in the distillation of a number of resins, particularly copal, is obtained in greater quantity. The raw asphalt oil was shaken with a concentrated solution of caustic potash, then distilled with steam, dried over calcium chloride, and finally distilled by itself from a retort provided with a thermometer. The oil begins to boil at 90° C., but the boiling point rapidly rises to 120° C. The greater part of the oil distils at 200° C., a smaller part from 200° to 250°. At the latter temperature there remains a small quantity of thick, strongly colored oil as a residue.

The following quantitative results are given. The portion boiling between 90° and 200° showed, at 15° C., a specific gravity of 0·817, and, by combustion, the following percentage composition:

*Ann. Ch. Pharm.*, **88**, 139.

| | Per Cent. |
|---|---|
| C. | 87·37 |
| H. | 11·65 |
| O. | 0·98 |
| | 100·00 |

That boiling between 200° and 250° showed a specific gravity of 0·868, and the following percentage composition:

| | Per Cent. |
|---|---|
| C. | 87·55 |
| H. | 11·56 |
| O. | 0·89 |
| | 100·00 |

The author calls attention to the fact that asphalt oil has exactly the same composition as amber oil, obtained by distilling amber, and further states that these oils are also similar in general conduct.

By the action of dilute nitric acid, asphalt oil is colored brown at ordinary temperatures; by heating it changes into a yellow gummy mass, which smells like musk and oil of bitter almonds. Concentrated nitric acid works in the same way, but more violently. Concentrated sulphuric acid dissolves, with evolution of heat, a part of the asphalt oil, while another part collects upon the surface of the thick, red-colored sulphuric acid solution. The separated oil was again treated with sulphuric acid, and then with alkali, and finally distilled with steam. The distillate thus obtained possesses a faint, pleasant odor, entirely different from the oil not treated with sulphuric acid. After dehydration by long contact with chloride of calcium, the oil was distilled; it began to boil at 90° C., but very little went over below 120°. The following fractions were separated: 90°–120°; 120°–150°; 150°–180°; 180°–200°; 200°–220°; 220°–250°. All these fractions were analyzed with practically the same results—C., 87·50 per cent.; H., 12·50 per cent. The part of asphalt oil not taken up by sulphuric acid shows, therefore, the formula $N(C_6H_5)$. These oils are insoluble in water, but easily soluble in alcohol and ether. They are only slightly attacked by concentrated sulphuric acid, and do not dissolve in concentrated nitric acid. By heating with nitric acid,

only a small part is changed into a heavy yellow oil, which, by distillation with steam, is obtained colorless. In chemical constitution these oils agree with the volatile oils which separate on treating amber oil with concentrated sulphuric acid.

R. Kayser,* in 1879, published the results of an investigation upon the products obtained from a number of asphalts of different sources, by the action of the solvents alcohol and ether, and also of products obtained by destructive distillation of the original asphalts. Kayser made quite a large number of elementary analyses of asphalts, and of products obtained from them by the action of alcohol and ether, and by destructive distillation. In his analyses were included determinations of carbon, hydrogen, sulphur, nitrogen and ash. In the older investigations, the presence of sulphur appears to have been overlooked or ignored. In many of them nitrogen, also, was undetermined.

In Kayser's paper, formulæ for the products analyzed were proposed in accordance with the requirements of the analytical results. Bodies "of constant boiling point" were obtained by fractional distillation of the products obtained from the destructive distillation of the original material. The asphalts included in this investigation were taken from the following sources: from Syria, Trinidad, Bechelbronn, Maracaibo and Barbadoes. The following table shows the results obtained by Kayser in his elementary analyses of the various asphalts studied by him:

ANALYSES OF VARIOUS ASPHALTS BY KAYSER.

| | *Syria.* *Per Cent.* | *Trinidad.* *Per Cent.* | *Bechelbronn.* *Per Cent.* | *Maracaibo.* *Per Cent.* | *Barbadoes.* *Per Cent.* |
|---|---|---|---|---|---|
| Carbon | 80·00 | 78·80 | 86·60 | 81·65 | 87·04 |
| Hydrogen | 9·00 | 9·30 | 11·40 | 9·59 | 9·56 |
| Sulphur | 10·00 | 10·00 | 1·40 | 8·03 | 2·67 |
| Ash | 0·60 | 0·50 | 0·50 | 0·34 | 0·24 |
| Nitrogen | 0·40 | 1·40 | 0·30 | — | — |
| Oxygen | — | — | 0·40 | — | — |
| | 100·00 | 100·00 | 100·60 | 99·61 | 99·51 |

* *Mittheilung aus dem Laboratorium des Bayerischen Gewerbemuseums zu Nürnberg.*

In the first three cases the figures are the averages of a number of well-agreeing determinations; in the two others (Maracaibo and Barbadoes), the figures are the results of single determinations.

Although Kayser claims to have obtained pure substances as the result of fractional distillation of the Syrian asphalt oil, and gives to these bodies definite formulæ as the results of elementary analysis, the evidence given by him of their purity is hardly satisfactory, since he does not, in any case, give the exact range of boiling point, but gives the boiling points in round numbers. Furthermore, he describes a number of them as yellow and brownish-yellow in color, the first one only (boiling at 96°) being described as water-white. The following table gives the formulæ ascribed by Kayser to the ten fractions obtained in the distillation of Syrian asphalt oil:

| | *Boiling Point.* | *Formula.* | *General Formula.* |
|---|---|---|---|
| I. | 96° C. | $C_{12}H_{24}S$ | $C_nH_{2n}S$. |
| II. | 158° C. | $C_{20}H_{40}S$ | $C_nH_{2n-8}S$. |
| III. | 170° C. | $C_{22}H_{42}S$ | $C_nH_{2n-10}S$. |
| IV. | 188° C. | $C_{24}H_{48}S$ | $C_nH_{2n-12}S$. |
| V. | 221° C. | $C_{28}H_{54}S$ | $C_nH_{2n-14}S$. |
| VI. | 225° C. | $C_{30}H_{58}S$ | $C_nH_{2n-12}S$. |
| VII. | 229° C. | $C_{28}H_{56}S$ | $C_nH_{2n-14}S$. |
| VIII. | 233° C. | $C_{28}H_{56}S$ | $C_nH_{2n-16}S$. |
| IX. | 240° C. | $C_{28}H_{56}S$ | $C_nH_{2n-16}S$. |
| X. | 265° C. | $C_{36}H_{84}S$ | $C_nH_{2n-18}S$. |

Without further and more satisfactory evidence the conclusions here arrived at by Kayser seem unwarranted.

Although there are in print many articles of value on the commercial applications of asphalt, and some giving the results of elementary analysis, I have failed to find any publications other than the ones already considered, and an important paper by Peckham, to be referred to later, which throw light upon the real nature of the asphalts, or which definitely describe pure products obtained from them.

The present investigation of gilsonite had for its object the isolation of such single hydrocarbons, or classes of hydrocarbons or their derivatives, as would give some information as to the nature of the material itself.

Although this object has not yet been fully attained, such progress toward that end has been made as to indicate that definite results are near at hand. As the work must be interrupted for a few months, I have thought best to give an account of the results thus far obtained.

Gilsonite* is a black, brittle material, pulverizing readily to a dark brown powder, which is inclined to stick to the sides of the mortar when finely divided. It is lighter than water, and entirely soluble in carbon bisulphide.

Absolute alcohol dissolves 54·6 per cent., if repeatedly treated with the hot liquid until no further action is noticeable. The following figures, showing the solubility in alcohol were obtained: 2·2298 grams of gilsonite gave 1·2178 grams of insoluble residue, while the dissolved matter weighed 1·01 grams.

Ether does not dissolve gilsonite entirely, as shown by two successive treatments of a small quanity of gilsonite with a large excess of ether; the solution obtained is red in color, with a greenish fluorescence. Absolute alcohol added to the ether solution gives a precipitate. Petroleum ether, glacial acetic acid and chloroform are partial solvents.

The residue obtained by evaporating the petroleum ether solution is black in color, hard, brittle and differs markedly from the material soluble in alcohol. It resembles the original gilsonite quite closely. Only a small percentage of gilsonite remains undissolved in petroleum ether after twenty-eight successive treatments with the solvent. This insoluble residue is black and very easily pulverized.

The residue obtained by evaporating the alcoholic solution is reddish-brown in color, solid at ordinary temperatures, but soft enough to be easily cut with the finger nail. On being heated on the water bath it becomes softer, and at 100° C. is liquid enough to flow.

The residue, insoluble in alcohol, is a black, brittle substance, becoming brownish in color on pulverizing, and resembling in appearance the original gilsonite.

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* The material upon which I have worked was kindly furnished by the Gilson Asphaltum Company, of St. Louis, Mo.—W. C. D.

ANALYSIS.

To determine the volatile matter, fixed residue and ash, weighed quantities of gilsonite were heated in a platinum crucible, first covered, and afterwards, when all volatile matter had been expelled, uncovered. 0·2391 gram gilsonite gave 0·1041 gram fixed residue, and 0·0003 gram ash. These figures show that gilsonite yields:

| | *Per Cent.* |
|---|---|
| Volatile matter | 56·46 |
| Fixed residue | 43·43 |
| Ash | 0·10 |
| | 99·99 |

Working on a larger scale, and distilling a weighed quantity of gilsonite from a retort, the following result was obtained: 136·1 grams of gilsonite gave 76·1 grams of distillate. The percentage of volatile matter is thus 55·9. Comparing this result with that above it is evident that all the volatile matter is condensable.

*Elementary Analysis.*—Combustions were made with lead chromate in a current of oxygen:

(I) 0·6160 gram gilsonite gave 1·9872 grams $CO_2$, and 0·55615 gram $H_2O$.
(II) 0·4715 gram gilsonite gave 1·5318 grams $CO_2$, and 0·4195 gram $H_2O$.

Percentages of carbon and hydrogen found:

| | *I.* | *II.* |
|---|---|---|
| Carbon | 87·99 | 88·61 |
| Hydrogen | 10·03 | 9·89 |

The determination of sulphur in gilsonite proved to be a matter of some difficulty, and, before success was finally attained, all the various methods of determining sulphur in organic compounds were tried.

Sauer's method of burning in oxygen and passing the products of combustion into a hydrochloric acid solution of bromine was found inapplicable, on account of the great difficulty of securing steady vaporization of the volatile constituents of the gilsonite. Owing to the tendency which, at certain stages of its distillation, gilsonite shows to foam or volatilize very rapidly, some of this vapor almost inevitably escapes combustion in the oxygen. The writer has

used this method with success in the case of volatile petroleums, and is, therefore, sure that the difficulties which stand in the way of its application to gilsonite are inherent in the substance, as above described.

Good results in the determination of sulphur were finally secured by a combination of the Carius method of oxidizing with nitric acid in an open vessel, and then heating the unoxidized solid material with magnesia in a platinum crucible, as recommended by Eschka in determining sulphur in coals. The sulphur is finally weighed as $BaSO_4$. When gilsonite is treated with a large excess of concentrated nitric acid, under the influence of heat in an open vessel, brown fumes are abundantly given off, and, after a time, the gilsonite entirely dissolves, giving a dark red solution, which becomes constantly lighter as the heating is continued. If at the point when the gilsonite is just completely dissolved the solution is poured into cold water, a reddish-brown precipitate, closely resembling ferric hydroxide is immediately thrown down. This precipitate contains practically all the sulphur, only traces having been converted into sulphuric acid by the oxidizing action of the nitric acid. This precipitate was washed with water, dried, then mixed with magnesia, and the sulphur determined as already described.

(I) 1·30215 grams gilsonite gave 0·1231 gram $BaSO_4$.
(II) 0·9581 gram gilsonite gave 0·09414 gram $BaSO_4$.

| | |
|---|---|
| Percentage of sulphur from I | 1·29 |
| Percentage of sulphur from II | 1·34 |

The results obtained by other methods did not show sufficiently close agreement, ranging, however, only between the limits 0·93 and 1·59 per cent.

The percentage composition of gilsonite, therefore, appears to be:

| | *Per Cent.* |
|---|---|
| Carbon | 88·30 |
| Hydrogen | 9·96 |
| Sulphur | 1·32 |
| Ash | 0·10 |
| Oxygen and Nitrogen (undetermined) | 0·32 |
| | 100·00 |

DRY DISTILLATION OF GILSONITE.

Before undertaking the direct distillation, some of the finely powdered gilsonite was subjected to distillation with steam. The receiver showed a slight film of colorless oil, of pleasant odor, floating upon the water. The amount of oil was so small that nothing further could be done with it.

In the dry distillation the material was first distilled from a tubulated retort provided with a thermometer, the bulb of which was in the liquid. Distillation began at 150° C., but very little came over; the temperature rose quite rapidly; but before the distillation was fairly under way, the thermometer had to be removed as the temperature rose above 300° C. The first drops of oil coming over were light yellow; this color became darker as the distillation progressed. The operation could not be carried to completion on account of the softening of the glass, although with a hard glass retort on another occasion the distillation was continued until nothing but coke was left. Glass retorts were finally replaced by one made of six-inch iron pipe, capped at both ends, and connected with a smaller pipe to serve as condenser. Energetic foaming takes place at two different stages; this fact necessitates the greatest care in the regulation of the heating flame, and it is a very difficult matter to avoid the carrying over of undistilled matter, particularly when using an iron retort. Toward the end of the distillation ammonia is quite freely evolved. The distillate is lighter than water, is of a reddish-brown color, and shows a greenish fluorescence; the odor is highly unpleasant. It was distilled with steam. This treatment separates the oil into a portion readily volatile with water vapor, and of a yellow color, and a thick, black, tarry-looking oil which remains in the distilling flask.

*Oil Volatile with Water Vapor.*—The volatile portion was distilled again with steam, becoming, as a result, much lighter in color, but on standing it changes from a lemon-yellow, to a reddish tint. The odor is suggestive of sulphur compounds. The oil, after drying over calcium chloride, was next treated with concentrated sulphuric acid, the two liquids being placed in a round-bottomed flask, and thoroughly shaken

together; the acid became very dark red, almost black in color, sulphur dioxide was freely evolved and so much heat was produced that the flask became too hot to handle. This treatment, using afterward fuming sulphuric acid instead of ordinary concentrated acid, was repeated until, after twenty-five or thirty treatments with fresh acid each time, no further action could be detected. The oil at this stage, after washing with alkali and water, and drying over calcium chloride, is water-white, of a pleasant odor, much like that of highly refined petroleum after repeated distillations over metallic sodium.

Concentrated nitric acid and a mixture of concentrated nitric and fuming sulphuric acids have no effect upon it, even after prolonged heating on the water bath. It dissolves bromine, but without chemical action or evolution of hydrobromic acid. The washed and dried oil, subjected to distillation, begins to boil at 125°, and, with the exception of a few remaining drops, is entirely distilled when the temperature reaches 263° C. After standing for six months over calcium chloride, the oil is still perfectly water-white. The total bulk of the oil so treated with sulphuric acid is very much reduced; perhaps less than 10 per cent. survives the action of the acid. The chemical inertness of this oil shows that it belongs to the paraffin series. Judging from the regular and uniform rise of temperature in distilling, the oil is just as complicated a mixture of different hydrocarbons as is highly refined petroleum.

The sulphuric acid used in treating this oil was preserved for subsequent investigation. The action of sulphuric acid was apparently largely of an oxidizing character, judging from the copious evolution of sulphur dioxide, which was so vigorous at times that the liquid almost foamed out of the flask. A part of this spent acid was diluted with water; a milky turbidity was produced, and, on warming and allowing to stand, a green oil rose to the surface. This oil has an odor something like that of pennyroyal. The dilute acid was neutralized with precipitated chalk, the resulting gypsum filtered off, and the solution evaporated. A sticky, gummy substance, separated when nearly all the water was

driven off; when perfectly dry the material became a pulverisable solid, light in color, deliquescent, very easily soluble in water, and entirely insoluble in ether.

The oil which rises to the surface on diluting the spent sulphuric acid becomes, on standing, a thick, tenacious black tar, of such consistency that, on being stirred, it takes a long time to spread again over the surface of the water. This was skimmed off and heated with water on the water bath; it seems to dissolve entirely in hot water. On standing over night, a small amount of oil was found floating on the surface; this was skimmed off; on pouring off the aqueous solution a heavy oil, small in amount, was found at the bottom. The aqueous solution was transparent, and greenish in color. On evaporating off the water, a thick, dark green, almost black, oily-looking liquid was left behind; this dissolves readily and quickly in cold water. It is entirely soluble in alcohol, but only partly soluble in ether and carbon bisulphide. The alcoholic solution is green, and looks like the aqueous solution. Ether becomes yellow in color, but does not dissolve much; carbon bisulphide acts much like ether. The aqueous solution was extracted with ether until the latter was no longer colored. The aqueous solution was then treated with barium carbonate, to neutralize a small amount of sulphuric acid, and the barium sulphate filtered off. This neutralisation caused the green color to change from green to reddish brown. On evaporation, a mass remains which is black and sticky before complete dryness, but when dry is a brown powder, easily soluble in cold water.

Prof. S. F. Peckham,* in an article entitled "Nitrogen Content of California Bitumen," has shown that the crude petroleums of California contain esters made up of basic oils in combination with an exceedingly viscous, feebly acid, tar. He says when the crude oils are treated with dilute acid, this acid radical forms a hydrate which produces, with the other constituents of the petroleum, an emulsion, from which the aqueous acid solution of the basic oils is sepa-

* *American Journal of Science, III*, **48**, 250.

rated with much difficulty. In the case of distillates of high specific gravity, the acid radical, or its hydrate, does not dissolve in the oil, so that the acid solution of the bases, the acid hydrate and the oil not acted on by the dilute acid form three distinct layers in the containing vessel. Peckham states that the basic oils belong to the pyridine and quinoline series. He has shown also that by removing these basic oils and the tarry, viscous acid hydrates with which the basic oils were previously combined, the burning and lubricating oils afterwards produced by refining are much superior to those obtained when the above-mentioned bodies are not removed.

If, in the case of the oil volatile with steam, I use dilute sulphuric acid and warm for a time on the water bath, shaking frequently, the dilute acid becomes colored yellowish-red from it; by the addition of sodium hydroxide solution a yellowish-white precipitate is obtained. On standing, a brown oil rises to the surface. It has an odor which reminds me of quinoline rather than pyridine.

From the general similarity between the bodies obtained by Peckham and those resulting from my treatment of oil volatile with steam, I feel no hesitation in expressing the conviction that the bodies obtained from this oil correspond entirely with those obtained by Peckham from the California bitumens. The existence of these basic oils in the California petroleums and in gilsonite is evidence both of their relationship and of their animal origin. Since gilsonite is a hard, brittle solid, and thus removed as far as possible from the petroleum from which it may have been derived by oxidizing agencies, it is a matter of some general interest to note the resemblance in constitution, as shown by these basic compounds. According to the result of analysis of gilsonite, which I have submitted, there appears to be not more than 0·5 per cent. of nitrogen in it, while in the California petroleums the amount exceeds one per cent. In general, the percentage of nitrogen is less in the asphalts than in the petroleums, according to the analytical results thus far obtained. I propose to continue the study of the nitrogen compounds from gilsonite during the present year.

*Oil Not Volatile with Water Vapor.*—After removal from the water distilling flask this oil appeared thick, black and tarry. It was dried by standing for two weeks over calcium chloride. The first distillation was conducted in a 250 c.c. retort. The boiling began at about 175° C., rising quite rapidly to 230° C., after which the rise was more gradual. The distillate was divided arbitrarily into five fractions. On distilling again the first or most volatile fraction, the boiling began at 175°, rising quite rapidly to 230°, and from that more slowly to 300° C., when only a few drops remained. The distillate was reddish in color, but lighter than it was before the second distillation. There was not much evidence of cracking in this distillation. The remaining fractions are thus evidently liquids boiling at points above 300° C. No solid body separated in the course of any distillation, but the distillates were in all cases liquids of various degrees of consistency.

*Action of Nitric Acid.*—The highest boiling fraction was subjected to the action of concentrated nitric acid. The weight taken amounted to nearly 100 grams. Violent action took place with abundant evolution of red fumes, accompanied by occasional slight explosions, producing vortex rings in the red vapor and a popping sound. The flask became too hot to touch. After cooling, a quantity of semi-solid oil remained on the surface; the acid was then poured off into cold water. This produced a yellow precipitate of a solid body, which, when collected and pressed into a lump, took a purple color. This, after being pulverized in a mortar, proved to be nearly insoluble in ether, but readily soluble in absolute alcohol; it would not crystallize from this solution. Subjected to the slow action of somewhat diluted nitric acid, the oil, after heating on the water bath for a number of days, gradually becomes thicker, until, finally, it reaches the solid condition, appearing then as a purple solid, having a musk-like odor. It is soluble in ether and alcohol, somewhat more so in the latter. Alkalies slowly dissolve most of it, but some oily-looking matter remains undissolved. The investigation of this material will be continued.

ACTION OF NITRIC ACID UPON GILSONITE.

At first gilsonite was treated with dilute nitric acid, the former in large excess; no definite results were reached in this way. Finally, the nitric acid was employed in concentrated condition and in large excess, when it was found that after about twenty-four hours' continuous heating, during which time brown fumes were continually given off, the gilsonite had entirely dissolved, giving a dark red solution. When this solution is poured into water, a flocculent brown precipitate is produced, looking almost exactly like freshly precipitated ferric hydroxide. This was washed repeatedly with water until all nitric acid had been removed, and then dried on the water bath. Alcohol dissolves most of this substance, leaving undissolved a small quantity of dark-colored material. On evaporation a dark, brittle substance is left. This is soluble in concentrated nitric acid; on pouring into water, a precipitate like the original is produced. Ether dissolves less of the material than alcohol, the greater part being insoluble in ether. The ether solution is yellow in color, and on evaporation leaves a hard, shiny, reddish-yellow varnish-like residue, which may be ground to a fine powder. It dissolves readily in concentrated nitric acid, and on re-precipitating by the addition of water, appears as a light yellow, almost white, precipitate of flocculent character; on heating with water this precipitate melts, shrinks very much, and becomes, on cooling, a hard, brittle substance. It was redissolved in nitric acid and reprecipitated with water a number of times, but no perceptible change in it resulted from this treatment. Alkalies and ammonium hydroxide dissolve it readily; from the solutions thus obtained the substance is re-precipitated, apparently unchanged, by dilute acids. The material thus appears to be an organic acid in apparently quite pure condition. The original precipitate from nitric acid, on being heated in a dry test tube, swells up, giving off a dense white smoke and distilling off a colorless oil, heavier than water. A sort of deflagration takes place, which continues after the removal of the heat. This deflagration appears also with the material dissolved by alcohol, but not at all in the case

of that dissolved by ether. From this it appears that the original brown precipitate produced by pouring the nitric acid solution into water, is a mixture of different substances, one or more of which, as indicated by the deflagrating action, are nitro-compounds easily decomposed by heat, with attendant rapid oxidation. Another ingredient of the mixture is an acid insoluble in water and probably a single chemical compound, which is to be made the subject of further study.

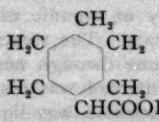
The filtrate obtained on removing the brown precipitate is of a reddish color. This was evaporated upon the water bath, removing the excess of acid and leaving finally a sticky, dark red, gummy mass, soluble in water. As the oxidizing action of the nitric acid in the course of this evaporation appeared to be quite considerable, it was thought best in other cases to neutralize the acid filtrate first with ammonia and then evaporate, thus avoiding further oxidation. The mixture of organic matter and ammonium nitrate thus obtained was first tested as to solubility in ether, but this had very little action in dissolving anything. Absolute alcohol was then tried, with the result of dissolving quite a considerable quantity of organic material, together with some ammonium nitrate. The treatment with alcohol was continued until it came through nearly colorless, being at first dark red. The alcohol was distilled off on the water bath, and the residue, which was liquid when hot, became crystalline on cooling, due, probably, to the separation of ammonium nitrate. It was dissolved in water. On adding lead acetate to this, a light yellow precipitate was formed at once. This was washed, and, on treating with hot water and hydrochloric acid, it was all dissolved. On cooling, lead chloride settled out; this was filtered off, and hydrogen sulphide passed through the filtrate to secure the complete removal of lead. No lead sulphide was, however, obtained. Upon evaporating again, a reddish liquid was left behind, together with some crystals of a substance readily soluble in water and in ether, and giving a strong acid reaction.

The material remaining undissolved by the absolute alcohol above referred to was dissolved in water, lead

acetate was added to this and a heavy greenish-gray precipitate was thrown down. This was filtered and washed with hot water, and then hydrochloric acid was added, which caused the solution of nearly the whole; on filtering this, the solution coming through at first clear, soon separated material looking like the original, and not at all crystalline. The investigation of this material will be continued.

The alkali salts of all the acids obtained are readily soluble, and, on shaking, the solutions give a lather reminding of soap solutions, although they do not appear soapy to the touch. The lead salts are all insoluble in cold water. None of the salts appeared to be crystallisable.

Hell and Medinger* have described an acid occurring in Wallachian petroleum; this, in the conduct and general character of its salts, is quite similar to some of the acids referred to in this paper. The authors just named purified the acid by conversion into the methyl and ethyl esters and fractioning, and afterwards obtaining the pure acid. From the conduct of this acid and its salts, they ascribed to it the formula $C_7H_{12}O_2$, and regarded it as having the structure



or, in other words, a naphthene derivative.

As a result of the present investigation, a method of obtaining from gilsonite a number of acids has been outlined. By further study of those acids and their derivatives, a knowledge of the hydrocarbons present in the mineral may be gained. The distillation experiments have shown that a number of radically different series of hydrocarbons is obtained, and that the paraffin series is one of them, and very probably, also, the naphthene series is another. No aromatic hydrocarbons appear to be present, or, at most, only in small quantity, as in no part of the work

* *Berichte d. deutsch. Chem. Ges.*, **7**, 1216, and **10**, 451.

have derivatives of these bodies suggested themselves. Conclusions drawn from distillation products of a mineral hydrocarbon, as to the constitution of the latter, are necessarily unsafe, on account of the decompositions which take place during the distillation. Much safer conclusions may be drawn from products obtained without distillation from the original material directly by the action of reagents such as nitric and sulphuric acids.

Markownikoff,* who isolated aromatic hydrocarbons in petroleum from Baku, condemns the use of bromine or nitric acid to detect aromatic hydrocarbons, since, he says, these reagents are liable to give aromatic derivatives from the naphthenes. He prefers, on this account, to use sulphuric acid, obtaining the sulphonic acid, and from this to pass to the hydrocarbon by distilling with lime from an iron retort. The action of concentrated sulphuric acid upon gilsonite is now under investigation by the writer, but, as yet, without definite or even promising results.

In conclusion, I may express the hope that in a future paper I may be able to give definite conclusions resulting from the study of the acids referred to in this communication, and also results of further study of basic oils. I am indebted to Prof. S. P. Sadtler for aid in my review of the literature, and to Miss A. T. Coons and Mr. A. H. Scott, of Swarthmore College, for valuable aid in the laboratory.

SWARTHMORE COLLEGE, PA., June 18, 1895.

## NOTES AND COMMENTS.†

### TELEGRAPHING WITHOUT WIRES.

Prof. A. E. Dolbear, in the *Electrical Engineer*, says: The increasing interest in the attempts to telegraph without wires both here and abroad makes it worth while to make mention of some facts which have been forgotten or ignored, and I venture to point out that the method which has lately been employed so successfully in England for telegraphing across a sheet of water between three and four miles wide with no connecting cable was fully described by Prof. John Trowbridge, of Harvard University, in

* *Annalen d. Ch. u. Pharm.*, **234**, 89.

† From the Secretary's monthly reports.

1880. He made his original researches between the Observatory in Cambridge and the city of Boston, between which is a time signal wire having the circuit broken by clock once a second. He found he could hear the clock-beats a mile away from the line by connecting a telephone to a wire 500 or 600 feet long and grounding their ends parallel with the circuit.

His experiments and conclusions are detailed in a paper given before the American Academy of Arts and Sciences, and are published in its *Proceedings* for 1880. How completely he covered this ground of doing telegraphic work by means of earth conduction will be seen by the following quotations from those *Proceedings*:

"The theoretical possibility of telegraphing across large bodies of water is evident from this survey which I have undertaken.

"Theoretically, however, it is possible to telegraph across the Atlantic Ocean without a cable. Powerful dynamo-electric machines could be placed at some point in Nova Scotia, having one end of their circuit grounded near them and the other end grounded in Florida, the conducting wire consisting of a wire of great conductivity and being carefully insulated from the earth, except at the two grounds. By exploring the coast of France, two points on two surfaces not at the same potential could be found, and by means of a telephone of low resistance the Morse signals sent from Nova Scotia to Florida would be heard in France."

This is precisely what is being done in England, carrying out Trowbridge's method. In the various descriptions of methods and operations which I have seen there is no mention of the work of Trowbridge, and whatever merit and utility there may be in this method of doing telegraph work belongs to him. Shortly after the publication of the paper from which I have quoted, Dr. Edward Everett Hale wrote a short story for the *Atlantic Monthly*, in which these earth sheet currents played an important part. Beyond that, I have never seen mention of the discovery, for it was a discovery, and an important one too, that slight currents could be detected at relatively great distances from their source by means of a telephone connected to the ground.

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## THE CHICAGO CANAL AND LAKE COMMERCE.

Those interested directly in the commerce of the great lakes are manifesting much interest, and more or less apprehension, in regard to the reduction in water level that will follow the completion of the Chicago drainage canal, and the effect on the lake carrying trade. Careful calculations have been made to show the fall that will result when the canal is flowing at its maximum and minimum rates, and estimates have also been made of the decrease in capacity of the lake fleet due to a permanent reduction of the water level. From a report made by Thomas T. Johnston, assistant chief engineer in charge of the hydraulic work of the canal, we find that the level of Lake Michigan will be lowered between five and six inches when the canal is taking the maximum quantity, 600,000 cubic feet per minute. At the

minimum flow of the canal, 300,000 cubic feet per minute, the reduction will be only a little over one inch. The former estimate is made when Lake Michigan is at its highest normal level. It is thought that the average reduction for the average flow through the canal will be between three and four inches.

Regarding the effect on lake traffic of a reduction in level, we find considerable data in a report prepared by C. H. Keep, Secretary of the Lake Carriers' Association, at the request of Major E. H. Ruffner, Corps of Engineers, U. S. Army. This report is an estimate of the decrease in capacity of the lake fleet caused by a fall of three, six or nine inches in the mean level of the lakes. The list of vessels on the great lakes engaged in the carrying trade and of sufficient importance to be classed for insurance, was obtained from the *Inland Lloyd's Register*. It was assumed that all the vessels not classed were too small to have their carrying capacity affected by a lowering of the levels within the limits set for the investigation. Vessels known to be of light draft and those under 250 tons net register were not considered. The estimate is, therefore, restricted to vessels carrying package freight, grain, coal, ore and lumber. These vessels were arranged in eleven different classes or groups, according to size and carrying capacity, and types of each class were selected to show what cargoes are carried at different drafts. From these data estimates would show how much the carrying capacity of the entire fleet would be diminished in the case of a single load for each vessel; but to find the decreased capacity for a season, it became necessary to estimate the number of full loads carried during the season. This was estimated as being twenty-five loads per season for steamers and fifteen loads for schooners, which would represent a total of 33,000,000 tons of freight carried in a season. Upon this basis the following results are obtained:

A lowering of the lake levels by three inches would produce a diminution of the carrying capacity of the lake fleet in a season amounting to 1,142,370 tons; a lowering of the lake levels by six inches would diminish the carrying capacity 2,284,740 tons; and a lowering of the lake levels amounting to nine inches would diminish the carrying capacity 3,427,110 tons. Turning these results into dollars and cents, and estimating the earnings of lake vessels at an average of 50 cents per ton of cargo carried, over and above cost of loading and unloading, a lowering of three inches would diminish the earnings of the fleet in a single year $571,185; a lowering of six inches would diminish the earnings $1,142,370, and a lowering of nine inches would diminish the earnings $1,713,555.

It is evident, particularly to those familiar with the wide fluctuations in the levels of the great lakes, due to natural causes, a dry or a wet season, that the accuracy of calculations of this character, no matter how carefully prepared, may be questioned. The initial factors in the problem are too uncertain to permit of unimpeachable conclusions being drawn. While the calculations are of great interest, their value, as outlining the probable effect of the completion of the canal upon lake commerce, may be doubted.—*The Iron Age.*

## THE "DEADLY" TROLLEY CAR FENDER.

Referring to the notorious inefficiency of the fenders at present in enforced use upon the surface electric roads in many of our cities, the *Electrical Engineer* strongly reiterates its belief, long before expressed, that "good brakes are more necessary to the cars than poor fenders; and we hope ere long to see public opinion intelligently directed to that part of the subject. But, with the best of brakes, suicide will remain possible to those who seek to kill themselves on the trolley lines. As one of the Philadelphia papers says, the city itself owes some duties to the citizens other than putting petticoats around the cars, and the necessity of rapid transit must not be subordinated to the unchecked carelessness of stupid foot-passengers. In other words, it approves the Berlin rule that arrests the man who is run over. Speaking of the children, it says, very sensibly: 'There is but one power that can keep children from the streets, and that is the power of the police. There is not a day that scores of children cannot be seen playing on the streets occupied by trolley lines, in every part of the city, and until they are forbidden by the police, and arrested when they disobey the order of the city authorities, there will be no safety for children, fenders or no fenders. Children must be protected by a stronger power than themselves, and the only power that can protect them in a great city is the power of the municipality.'

"The above quotation is a cheering sign that the discussion of trolley car accidents is at the stage when the truth is about to prevail."

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## SUCCESSFUL TRIALS OF THE ELECTRIC LOCOMOTIVE.

The recent trials of electric locomotives at Nantasket Beach, near Boston, and at Baltimore, have so satisfactorily demonstrated the superiority of this class of motor over the steam locomotive for short hauls, that it is now very generally admitted that the near future will witness a very extensive application of the new form of motive power for short branch lines, tunnel haulage, elevated roads in cities, and the like.

At the Nantasket Beach trials it is stated that a speed exceeding sixty miles an hour was attained; and the experiment demonstrated the utility of this motor for suburban traffic. The system went into practical and regular operation on the Nantasket Beach Railway at the end of June. The test made at Baltimore of the electric locomotive designed to draw trains through the tunnel, 7,430 feet long, in that city, was also highly successful. This and its companion—the first locomotives of the kind ever built—have each two trucks and eight wheels, sixty-two inches in diameter. Flexibly supported on each truck are two six-pole gearless motors, one for every axle. A maximum speed of fifty miles an hour is to be developed, and it is guaranteed that the locomotive will pull 1,200 tons at a speed of thirty miles an hour. When coupled to a six-wheel New York Central locomotive, the electric locomotive pulled it up and down the track at will, against the pull of the steam locomotive.